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Chapter 16

Individual Differences in Stress Reaction

James L. Szalma

Introduction

Research in individual differences in performance has a long history, dating to the emergence of psychology and psychometrics itself (e.g., Cattell, Galton; see Boring, 1950). However, there has been a disconnect between this tradition and that of experimental psychology (Cronbach, 1957). As the origins of human factors and human performance research were in applications of experimental psychology, the disconnect manifested in relatively limited scope of individual differences research in human factors and ergonomics. At the same time, modern emphasis on human-centered design raises questions regarding how the characteristics of the human interact with those of the interface/task to influence system performance and operator well-being. In this chapter I hope to demonstrate that a synthesis of Cronbach's two disciplines (a rapprochement?) is possible and of great importance for understanding performance under stress, and that an integrated framework, based on cognitive science approaches, already exists and can be applied to human factors research and design. I also discuss the implications of an individual differences approach for theories of stress and performance and summarize empirical studies applying this perspective to the evaluation of factors that influence performance, workload, and stress response in cognitive and perceptual tasks. Finally, future directions for application of an individual differences perspective to human factors research on performance under stress are discussed.

Group and individual differences: Different perspectives on the same problem

Experimental and human factors psychologists have traditionally treated variation in behavior across participants as error variance or "nuisance" variables (e.g., Kirk, 1995). However, the individual differences perspective views the "nuisance" as a central focus of interest, the "error" as meaningful variance to be partitioned (Karwowski and Cuevas, 2003). Neither approach, by itself, is adequate to fully understand human performance in complex task environments, an observation that is hardly new (Cronbach, 1957). However, the integration of these complementary approaches has emerged as an important issue for current and future efforts in human factors research and practice. The transition from solid state, inflexible interfaces to virtual, "soft" and flexible computer-based interfaces permits the adaptation of the display, and to some extent controls, to the needs and preferences of the individual user or operator. At the same time, increasing numbers of technologically savvy users have come to expect their devices and computer-based tools to be adaptable to their needs and preferences, and such a cultural shift will most certainly extend into work environments across multiple domains, including some military applications.

Human factors researchers and practitioners have been quite successful at identifying task and display characteristics that influence human performance (Wickens and Hollands, 2000), and applying them to interface design (e.g., Karwowski, 2006; Sears and Jacko, forthcoming). However, across many domains a common observation is that of individual differences in performance and behavioral response among groups of users or participants. Indeed, it is often the case in psychological research that "error" variance accounts for more variability than the manipulated or observed variables. It is unlikely that this substantial variability is entirely random, and systematic examination of person characteristics can contribute to understanding a larger portion of the variability in human-technology interaction and system performance. Such advances can then be applied to both interface and training design. For instance, an individual differences perspective can be applied to the design of adaptable displays that conform to user needs and preferences, and to training regimens to fit an individual's learning style and strengths/weaknesses with respect to skill sets (including stress training, cf. Driskell et al., this volume).

Ultimately the emphasis on group differences (or, more formally, differences in task and environmental characteristics that affect performance of individuals exposed to those conditions) *versus* an emphasis on individual differences provides different vistas onto the same phenomenon, human performance. They share similar overarching goals, to understand the factors that control or influence performance and apply this understanding to real-world problems in system design and performance. Note that although these "two disciplines of psychology" discussed by Cronbach (1957) have different perspectives on the analysis of human behavior, this distinction is often mislabeled or misunderstood as being one of nomothetic *vs.* idiographic research. Researchers can and have effectively applied idiographic methodologies to the study of individual differences, but in applied experimental psychology and human factors it is more often a nomothetic approach. It may seem a contradiction to examine how individuals differ from one another using an approach that seeks to identify *universal* lawful relations. However, one goal for individual differences research is to investigate the characteristics that individuals share that result in common behavioral response, and to identify which characteristics are associated with differences in response. A second goal is to determine how these correlations with performance are moderated by task and environmental variables. From this perspective, the characteristics of the person are as important as the characteristics of the task the person is engaged in and the interface he/she is using. This approach rests upon the adoption of a trait perspective, which proposes a finite number of characteristics that humans share that determine their unique individuality via how the traits are expressed and by the profile of the traits (for an extensive treatment of the trait concept see Matthews, Deary and Whiteman, 2003). Note that this perspective is not limited to the affective traits to be reviewed in this chapter, but also extends to cognitive and psychomotor capacities. Further, such capabilities need not be assumed to be "innate." For the purposes of individual differences in performance research, cognitive and psychomotor skills may be considered to be "traits" if they are sufficiently stable over extended periods of time. From this perspective the study of individual differences is also not restricted to stable traits. Transient *states* also play a role in processes of self-regulation and adaptation relevant for performance (e.g., see Matthews et al., 2002; Matthews and Zeidner, 2004).

The individual differences perspective in human factors and performance research

Many psychologists have argued that the proper unit of analysis for human performance, and particularly for stress research, is the interaction between the human and his/her social and physical environment (Lazarus and Folkman, 1984; Bandura, 1986, 1997; Carver and Scheier, 1998). This line of thinking has manifested in several forms, including the transactional perspective (Lazarus and Folkman, 1984; Lazarus, 1991, 1999; Scherer, 1999; Matthews, 2001), reciprocal determinism (Bandura, 1986), and the ecological approach to psychology – the perception-action cycle (Gibson, 1979; see also Flach et al., 1995; Hancock, 1997). In human factors this unit becomes the "system" composed of the human and the technology he/she is using. A fuller understanding of human performance and human-technology interaction depends on understanding not only the characteristics of each component separately (human and interface) but the characteristics of the cycle of the interaction between them as it unfolds over time. Understanding these dynamics will facilitate design of systems that support performance as well as improvements in interface design and operator training. Further, a more complete model of the dynamics of the transaction can be applied to development of mitigation strategies for dealing with the negative effects of high workload and stress. Adopting an individual differences perspective permits identification of the "person" part of the transaction, and can contribute toward a more detailed examination of the person-environment interaction as the fundamental unit of analysis in theory, research, and design.

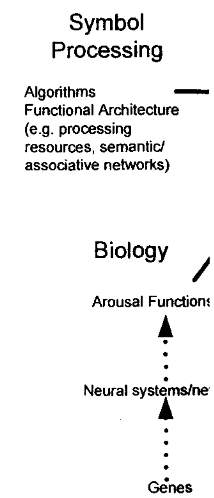
The problem: Need for theoretical integration and empirical coordination

There is a voluminous literature regarding how the characteristics of tasks, displays, and controls influence performance (e.g., Sanders and McCormick, 1993; Proctor and Van Zandt, 1994; Wickens and Hollands, 2000; Wickens et al., 2003). There is also a large literature on stress and performance (Hockey, 1983; Driskell and Salas, 1995; Hancock and Desmond, 2001; see also Conway, Szalma and Hancock, 2007; Hancock, Ross and Szalma, 2007). With respect to individual differences research, there is a substantial literature linking traits to performance on perceptual and cognitive tasks (e.g., Eysenck and Eysenck, 1985; Eysenck, 1992; Smith and Jones, 1992; Matthews et al., 2000; Matthews, Deary and Whiteman, 2003). There is also a rather large literature on personality traits and performance in work settings, but these tend to focus on organizational issues of personnel selection, job design, and job performance (e.g., see Barrick, Mount and Judge, 2001) rather than on specific cognitive tasks and human-technology interaction. In addition, most of this research does not derive general theories of the role of personality in performance and information processing applicable beyond a limited area of study (see Matthews, Deary and Whiteman, 2003, for a more in depth treatment of this issue). That is, these research traditions are not well linked conceptually or empirically, perhaps in part because researchers have tended to stay within their "niche" areas, not extending far beyond to incorporate findings from other research domains. For instance, there are substantial literatures on working memory capacity, cognitive style (operationalized as holistic/analytic processing), cognitive style (operationalized as field dependent/independent), spatial ability, attentional control, desire for control, cognitive failure, the need for cognition, and emotional stability (anxiety, neuroticism), to name but a few. However, these exist as distinct, relatively uncoordinated research areas, so that theories (and measures derived from them) in one domain are not often integrated with those of others, limiting progress in both theory and research (noteworthy exceptions are Extraversion and Neuroticism/Trait Anxiety; see Matthews, Deary and Whiteman, 2003; Matthews and Zeidner, 2004). Further complicating efforts at integration is the lack of consensus regarding the structure and processing of the cognitive, affective, and motivational subsystems (but see Dai and Sternberg, 2004), making it rather difficult to derive the general principles necessary for human factors applications. Indeed, the number of "basic" personality traits and the degree of their independence from one another is controversial (e.g., Eysenck, 1991; Block, 1995). Thus, the field is replete with "mini" theories that are difficult to integrate for purposes of application to real-world problems such performing stressful tasks under conditions of high workload. Such integration is crucial, however, for the design of interfaces as well as for improvement in the performance and well-being of human operators. If the individual differences in affective and cognitive traits and states are not incorporated into theories of human performance and principles of interface design, we are in essence neglecting half of the equation central to human factors and ergonomics, and conducting a very curious kind of "human-centered" design that neglects human personality, emotion, and motivation.

An additional challenge for individual differences research is one shared by other areas of behavioral science, particularly in the study of stress and performance. Specifically, it has proven difficult to systematically investigate the combined, interactive relationships of multiple traits (or stressors) with human performance and adaptation to task demands. Individual differences researchers usually focus on a single characteristic, as in stress research in which empirical investigations are often restricted to single stressors. However, real people cannot be summarized by a single characteristic, just as real environments do not consist of unitary stressors, and how these specific characteristics of the person and of the environment affect performance may depend to a large extent on the other characteristics of the individual. When a trait is "expressed" in a particular setting, other traits may be activated as well, producing complex interactions among multiple traits and multiple environmental events. Added to this is the problem of determining which relations among traits are multiplicative (e.g., emotional stability and extraversion; attentional control and anxiety?) and which may be additive (e.g., anxiety and spatial ability?). Hence, there is a need for more studies of the joint effects of two or more traits on task performance, workload, and stress, a daunting endeavor because of the complexity that results from combination of only two characteristics (cf. Hancock and Szalma, Chapter 1, this volume). An example will be presented later in this chapter that illustrates this complexity.

The solution: Theory integration at multiple levels of analysis

Meeting these challenges requires a comprehensive theoretical framework that incorporates the person and task characteristics, the mechanisms by which they interact and determine performance, and how these transactions can be shaped by changing the structure of the environment. A theoretical framework that articulates these mechanisms can then be integrated with current models of workload, stress, and performance. Fortunately such a framework exists that integrates trait theories with theories of cognition, emotion, and motivation using a cognitive science perspective to explain self-regulation and adaptation. The *cognitive-adaptive framework* presented by Matthews (1997a, 1999; Matthews and Zeidner, 2004) conceptualizes traits and transient states as composed of multiple self-regulatory processes at multiple levels of analysis (from the molecular genetic to higher level knowledge structures) and function (i.e., cognition, motivation, and emotion). With respect to level of analysis, Matthews (1999) included three levels of explanation, in terms of neurological/physiological mechanisms, cognitive architecture (information processing mechanisms), and knowledge structures (goals, strategy choice, appraisal and coping). Thus, the framework integrates processing oriented explanations (e.g., connectionist networks; see Matthews and Harley, 1993) of trait-performance relationships as well as content-oriented explanation (goals, interests, etc). The mechanisms by which these systems interact to support self-regulation were identified by Matthews and his colleagues as an "adaptive triangle," as shown in Figure 16.1 (Matthews, 1997b, 1999; Matthews and Zeidner, 2004). The three vertices of the triangle represent skills, self knowledge, and action (real-world adaptive behavior). Personality traits are represented in this model in terms of the characteristics of skills and self knowledge at multiple levels of analysis. Thus, in contrast to arousal theory (e.g., Eysenck, 1967) which posited a central arousal mechanism to explain variation in personality, the cognitive adaptive framework conceptualizes traits as distributed across multiple components of self-regulatory mechanisms. Although much research remains to be done to explore the dynamics of the interactions among the different components (e.g., traits, information processing, cognitive states, task demands, and environmental conditions), at different levels of analysis, the cognitive-adaptive framework



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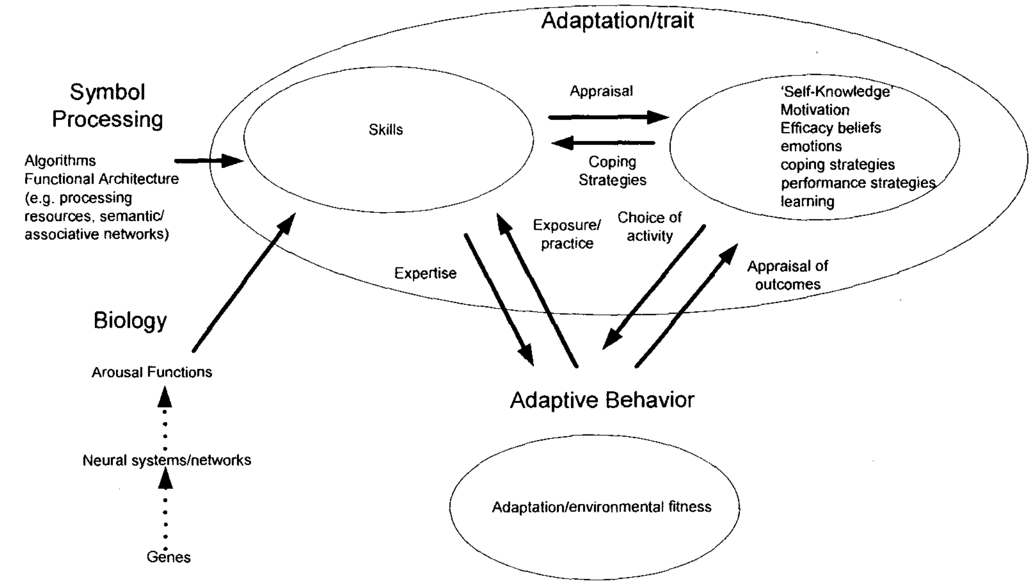

Figure 16.1 The cognitive-adaptive framework, illustrating the "adaptive triangle" of skill, knowledge, and action and the multiple levels of analysis
Source: Adapted from Matthews and Zeidner (2004).

provides the integration needed to guide systematic research to fully exploit the potential of the individual differences perspective for human factors research and practice.

From the cognitive-adaptive perspective, traits can be treated in a way analogous to Hockey and Hamilton's (1983) conception of the cognitive states associated with different sources of stress. They described the "broad band" approach to stress research, in which one systematically investigates the effect of a specific stressor (e.g., noise) on multiple psychological systems (arousal, working memory, selective attention, visual search, etc). As Hockey and Hamilton (1983) noted, adopting such a "broad band" approach permits the establishment of cognitive patternings associated with specific stressors. Thus, one can identify the differences in cognitive patternings (cognitive states across multiple stressors). This approach can be extended to investigation of individual differences in performance. That is, just as different *stressors* (noise, heat, etc) produce different cognitive patternings; different *traits* may be associated with distinct cognitive patternings (Matthews, 1992, 1999). An application of this approach to extraversion by Matthews (1992) is shown in Table 16.1. The cognitive patterning of neuroticism/anxiety is more difficult to establish, because the effect of neuroticism on different components of the cognitive architecture, and therefore performance, depends in large part not only on the level of threat posed by the environment (including task demands; see Table 16.1) but also the task motivation associated with the person-task interaction. In essence, it depends on the coping strategy selected, which is itself dependent upon the available resources for coping.

Table 16.1 The cognitive patterning of extraversion and anxiety/neuroticism

	Vigilance	Selectivity	Fast Responding Speed	Fast Responding Accuracy	STM	LTM	Attentional Resource Capacity
E	–[1]	0	+	–[1]	+	–	+[1]
A/N	#	+[2]	*	*	–	–[3]	–
	Response criterion	**Reflective problem solving**	**Semantic Memory Retrieval**	**General Intelligence**	**Affect**	**Self efficacy**	**Coping style**
E	–	–	+	0	+	+	Task
A/N	*	–[4]	–[3]	0	–	–	Emotion

Note: E = Extraversion; A/N = Anxiety/Neuroticism; STM = Short term memory; LTM = Long term memory; [1]arousal-dependent effects; [2]for negative or threat stimuli; [3]memory process can be *enhanced* for unhappy events or threat information; [4]effects occur only for more difficult or complex problems (see Eysenck and Eysenck, 1985, p. 299); *Results vary depending on task factors (e.g., threat *vs.* non-threat stimuli, task difficulty) and person factors (e.g., amount of effort expended; see Eysenck, 1992; Eysenck and Calvo, 1992); # Results vary across studies. After Matthews (1992, 1999) and Matthews et al. (2000).

Note that the cognitive-adaptive framework can help address the "it depends" problem in human performance research by specifying the cognitive, motivational, and emotional components that influence how an individual responds to different patterns of environmental demand. From this perspective it is not *which* traits are associated with adaptation and performance, but *how* trait profiles influence adaptation across different environmental conditions. The former approach is one of selection (i.e., which individuals are "best" at performing a particular task), but the latter can be applied to interface and training design by identifying task and environmental factors that offer the best motivational and affective "affordances" for effective adaptation. What is needed for application of the cognitive-adaptive framework to the human factors issues surrounding performance under stress is further integration of that perspective with models such as the maximal adaptability model of Hancock and Warm (1989) and the compensatory control model described by Hockey (1997). This will require systematic empirical research aimed at articulating the mechanisms underlying the cognitive processes involved in task performance (e.g., more precise description of mental resources and quantification of the basic dimensions of information processing and task performance; see Hancock and Szalma, Chapter 1, this volume; Hancock and Szalma, 2007; Szalma and Hancock, forthcoming).

Specific applications of individual differences

Approach to performance under stress

In the following sections applications of individual differences analysis of performance of stressful tasks is reviewed and results interpreted in terms of the cognitive-adaptive, maximal adaptability and compensatory control models. The tasks involved in most of these studies required selective, divided, or sustained attention for signal detection and discrimination. In addition, a study is reviewed that examined the relation of personality traits to shooting performance in a law enforcement field

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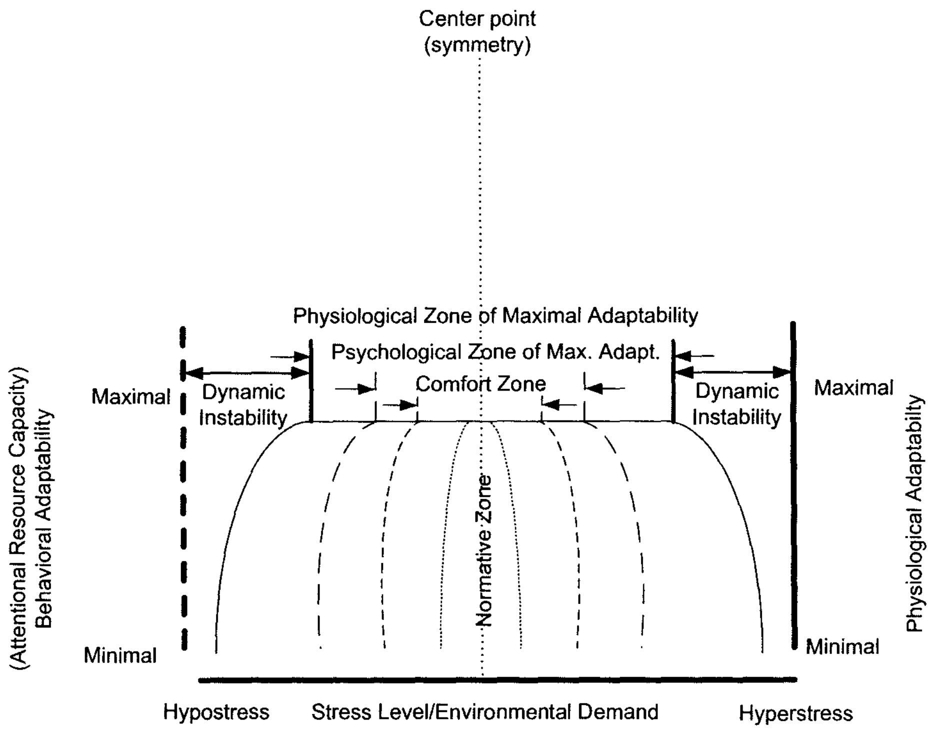

Figure 16.2 The Maximal Adaptability Model

Note: The adaptation is manifested in the plateau at the apex of the extended inverted-U which describes the zones of stable response to environmental demands (stressors). Failures in adaptation that occur when the input stress exceeds adaptive capacity are illustrated as declines in response capacity at multiple levels of function ranging from basal states and comfort zones to physiological adaptation. Note that the vertical line labeled "Center point" indicates that adaptation is symmetrical with respect to under- and over-stimulation, with the balance point residing within the normative zone.
Source: Adapted from Hancock and Warm (1989).

Role of disposition in attention: Pessimism, optimism, and extraversion

Maximal adaptability Model One of the key insights of the maximal adaptability model of Hancock and Warm (1989; see Figure 16.2) is that in many instances the tasks themselves pose the most proximal form of stress, and that decomposition of task characteristics to base axes of space and time can, in principle, permit prediction of physiological and behavioral adaptation to stress (see Hancock and Szalma, Chapter 1, this volume). The two base axes defined by Hancock and Warm (1989) were that of information structure and information rate. Information structure, a spatial dimension, refers to the organization of task elements. Information rate represents the temporal dimension of tasks. According to the model, the spatial and temporal properties of task contribute to the level of adaptive function by the individual. Thus, if the task and the environmental

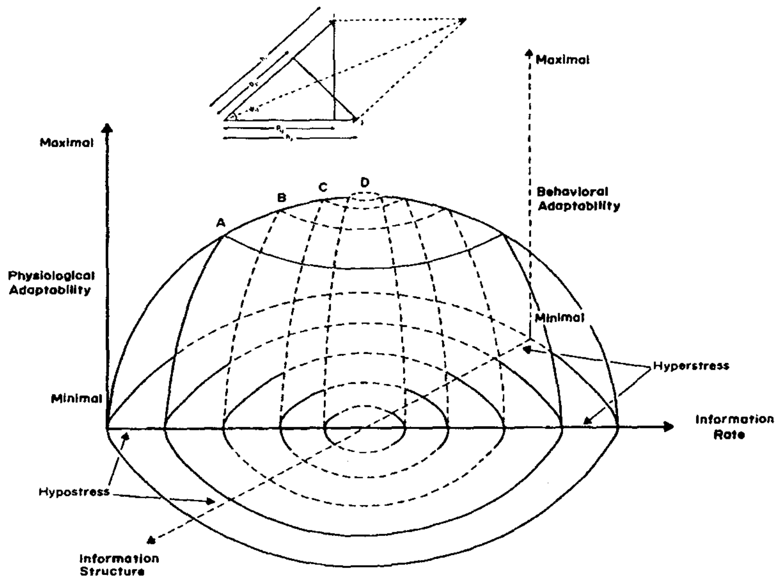

Figure 16.3 The Maximal Adaptability Model with Task Dimensions Included
Note: The stress/environmental base axis in Figure 16.2 has been decomposed into two separate component dimensions of environmental demands (tasks), information rate and information structure. These dimensions, if quantified, can be combined with other environmental inputs into a vector representation that indicates adaptive capacity.
Source: Hancock and Warm (1989).

characteristics (e.g., noise) could be accurately quantified, the adaptive state of the individual could be expressed as a vector combining these factors (see Figure 16.3).

Changes in spatial and temporal demand: A group differences analysis

A limitation of the Hancock and Warm (1989) model is that the two task dimensions have not been quantified, nor have their relation to one another been adequately explored. Understanding the nature of such interaction is a necessary first step toward realizing the vector representation Hancock and Warm (1989) proposed. Hence, Ross et al. (2003) examined the joint effect of intermittent bursts of 85 dB white noise and manipulations of temporal and spatial processing on performance. In that study, they manipulated the relative dominance of spatial and temporal task properties, and also employed a third condition in which these two properties were combined. Based on the maximal adaptability model it was hypothesized that if the spatial and temporal dimensions share a common mechanism, combining these demands into a task should impose greater demand and task-induced stress on the observer, resulting in poorer performance and higher perceived workload and stress. Ross and her colleagues did not find evidence supporting this contention, suggesting that the two dimensions may not share common perceptual mechanisms. However, the tasks they used were relatively easy and may not have been sufficiently demanding to produce the expected differences.

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Individual differences analysis: Dispositional optimism and pessimism

An individual difference analysis of the data from the Ross et al. (2003) study was conducted by Thropp et al. (2003) on the influence of dispositional optimism/pessimism on performance and self reports of stress state. Optimism/pessimism is known to affect performance and stress response. Individuals higher in pessimism tend to perform more poorly across a variety of domains, such as competitive swimming (Seligman et al., 1990), insurance sales performance (Seligman and Schulman, 1986), and even presidential candidates (Zullow, 1995). Optimism/pessimism may exert its effect in part by influencing general expectancies regarding performance and affective responses to performance success and failure (see Chang, 2002). Individuals high in pessimism tend to appraise events more negatively than those low in pessimism and adopt maladaptive coping strategies (Scheier and Carver, 1987; Szalma, 2002a). Attention is then redirected toward the self and managing the negative affect associated with pessimistic appraisals of the task. In contrast, the more positive expectations of individuals high in optimism may be associated with greater attention toward task-based processes, thereby improving performance and reducing stress symptoms. Note that these patterns are similar to those associated with Neuroticism (e.g., see Matthews, Deary and Whiteman, 2003).

Based on previous research, and the maximal adaptability model, it was expected that dispositional pessimism might be related to early "failures" of adaptation, i.e., subjective comfort (see Figure 16.2), manifested in increased levels of stress associated with tasks that imposed greater spatial-temporal demand. Note that in this and the other experiments described here, optimism/pessimism was measured using the optimism/pessimism (OPI), developed by Dember and his colleagues (Dember et al., 1989). Several studies using the OPI have indicated that optimism and pessimism are not polar opposites, but are partially independent dimensions (cf. Watson and Tellegen, 1985), with correlations of approximately $r = -0.5$ (Hummer et al., 1992; for a review see Dember, 2002). Thus, separate scores for optimism and pessimism are computed when that scale is applied.[1]

Consistent with expectation, Thropp et al. (2003) reported that pessimism predicted increased stress symptoms, evaluated along the dimensions of Task Engagement and Distress (Matthews et al., 2002), but these effects were restricted to tasks with spatial uncertainty. Pessimism also predicted greater use of emotion-focused coping, consistent with previous research (e.g., Scheier and Carver, 1987; Szalma, 2002b), but only in tasks with spatial uncertainty. For distress, optimism predicted lower post-task distress for tasks requiring either a spatial or temporal discrimination, although these effects were nullified when the pre-task state was accounted for in the regression model. Indeed, consistent with previous work (Szalma, 2002b), optimism predicted lower pre-task distress and higher pre-task engagement, while pessimism predicted higher pre-task distress and lower pre-task engagement. For a task requiring a temporal discrimination of the same stimulus, these effects were not observed. Pessimism and optimism were unrelated to performance, however. This may be due to the task-noise combination being of insufficient intensity to overwhelm the cognitive resources of individuals high in pessimism. However, the pattern of results suggests that the cognitive state of individuals high in pessimism differs somewhat from that of individuals low on that trait, although the emergence of such differences depends in part on the nature of the task demands (i.e., spatial uncertainty). Taken together, Thropp et al. (2003) interpreted these results to mean that pessimistic individuals disengage from the task in an attempt to cope (using emotion-

1 The OPI correlates well with other measures of optimism/pessimism (e.g., the Life Orientation Test (LOT); Scheier and Carver, 1987) when treated as one-dimensional. Careful reading of Scheier and Carver (1987), however, reveals that factor analysis of the LOT, which treats optimism-pessimism as a single dimension, also breaks down into two factors.

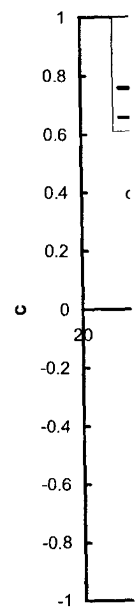
focused coping) with the greater demand associated with spatial uncertainty. This interpretation accords with the avoidance tendencies of individuals high in Neuroticism (e.g., Matthews, Deary and Whiteman, 2003; Matthews and Zeidner, 2004). Note that pessimism and optimism were related to different cognitive states. Specifically, pessimism was associated with decreased task engagement and optimism with lower levels of distress.

There have been inconsistencies across studies, however. Optimism is generally associated with greater positive affect, and would therefore be expected to be associated with greater task engagement. Indeed, evidence for such a link has been observed (e.g., Szalma, 2002b). However, Ross, Szalma, and Hancock (2004) reported that higher levels of dispositional optimism predicted *decreased* task engagement, but only for tasks requiring spatial discriminations (but no spatial uncertainty). Note that this was the case even after pre-task engagement measured prior to performing the task was accounted for in the regression model. In addition, the association of pessimism with stress in tasks with spatial uncertainty did not extend to a case in which there was no spatial uncertainty but a spatial discrimination was required. In sum, the relation between optimism/pessimism and performance, workload, and stress is not a simple one, and depends on the task characteristics (in this case the kind of perceptual discrimination required and the presence or absence of spatial uncertainty) and pre-task cognitive state of the individual.

Extraversion

Based on previous research on extraversion (see Matthews et al., 2003 for a recent review), it was expected that this trait might also be linked to performance, perceived workload, and stress associated with signal detection tasks, and that the relationship between this trait and the outcome variables might be moderated by the demands of the task (spatial/temporal) and the presence of an external source of stress (85dB*A* white noise). Thus, in the experiment described above, extraversion was measured using the adjective marker scale of the big five factors derived by Goldberg (1992). Thus, Thropp, Szalma, Ross and Hancock (2004) reported that extraversion was related to the performance and workload associated with perceptual discrimination of spatial and temporal stimulus properties. Specifically, higher levels of extraversion predicted more lenient responding, but only in a condition in which the individual was exposed to 85dB intermittent white noise and was required to discriminate stimulus duration. Individuals high in extraversion but who performed the same task under ambient noise conditions (60dB) achieved response bias levels similar to those lower in extraversion. Stated another way, white noise had the effect of inducing greater conservatism in responding, but only among those low in extraversion (see Figure 16.4). In addition, these effects were not observed in tasks with greater spatial demand. Across all conditions, however, higher extraversion predicted lower perceived workload, particularly perceived temporal demand.

The association of extraversion with response bias was consistent with the general finding that extraversion is associated with greater leniency in responding (Matthews, Deary and Whiteman, 2003), but these results also indicate that environmental stressors (e.g., noise) and the temporal and spatial characteristics of the task can influence the relation between extraversion and behavioral response. One possibility is that introverted individuals were more likely to find the noise distracting and, in combination with higher time pressure (i.e., perceived temporal demand) relative to extraverted individuals, may have had to make judgments faster and adopt a more lenient criterion than they do under quiet conditions. Given the impulsivity associated with extraversion (Eysenck and Eysenck, 1985), it may be that choosing the conservative criterion is more characteristic of the relatively non-impulsive introverts. However, research on the effects of stress and personality on signal detection theory measures have not produced consistent results.



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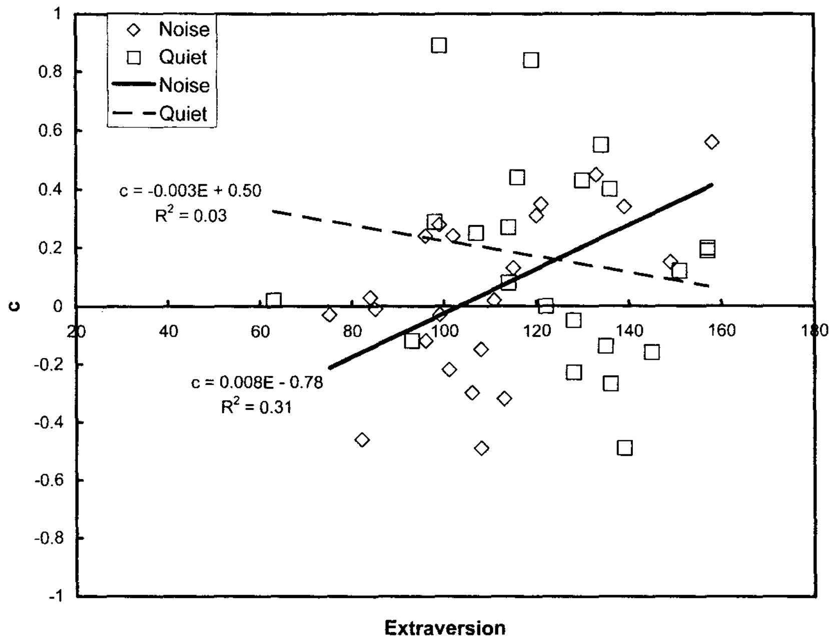


Figure 16.4 Response bias (c) as a function of extraversion and white noise exposure. The task required temporal discrimination without spatial uncertainty

A potential mechanism to explain differences in perceived temporal demand as a function of extraversion is shown in Figure 16.5. Hancock and Weaver (2005) noted that the attentional narrowing phenomenon that occurs under stressful conditions, which has been traditionally considered a narrowing in spatial attention (Easterbrook, 1959; Cornsweet, 1969; Hancock and Dirkin, 1983; Dirkin and Hancock, 1984, 1985) also extends to the temporal dimension. They further argued that these two dimensions share a common narrowing mechanism, by which the locus of attention to various cues changes as stress increases. Thus, to the extent that the stressed individual directs attention to *external* events time will *slow down*. By contrast, an *internal* locus of attention is likely to induce a subjective experience of time moving *faster*. One might therefore expect that traits that are associated with individual differences in attention (in this case, internal *vs.* external locus) would also predict the form of temporal distortion that occurs. Extraversion is one such variable (see Matthews, 1992; Matthews et al., 2000, 2003). Extraverts tend to over-estimate duration when performing tasks with stimuli that are low to medium in complexity (Eysenck, 1959; Zakay, Lomranz and Kazinz, 1984; but see also van den Van den Broek, Bradshaw and Szabadi, 1992). These effects may be due to the need for extraverted individuals for stimulation when the environment is relatively unstimulating (Zakay, Lomranz and Kazinz, 1984). If true, extraverts would be expected to have a greater tendency to orient their attention to external events relative to introverts. Based on the Hancock and Weaver (2005) model (Figure 16.5), extraverts would be expected to experience attentional narrowing along the temporal dimension that would manifest as a subjective experience of time "slowing down." Thus, when attention narrows under stress, individuals higher in extraversion would be more likely to exclude *internal* cues and drive attention toward external events. By contrast, individuals low in extraversion (introverts) would more likely exclude *external* cues and direct attention to internal events. If this is the case, then

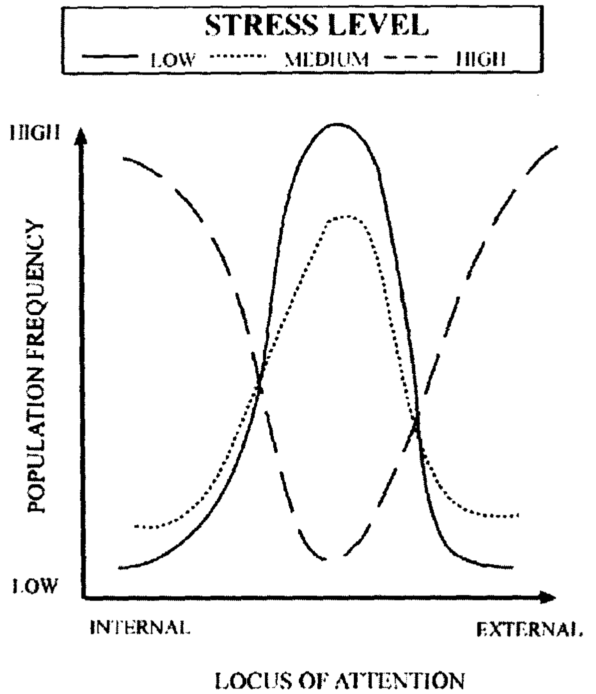


Figure 16.5 Relative frequency of locus of attention as a function of stress level
Source: Hancock and Weaver (2005).

extraverts should feel a relative slowing down of time and experience less temporal demand, while individuals lower on that trait will feel time speeding up and therefore experience higher temporal demand (see Figure 16.6).

Role of disposition in sustained attention: Pessimism and vigilance

Empirical research on sustained attention originated in studies examining performance decrements among military personnel engaged in monitoring RADAR displays (see Warm, 1984), but vigilance remains a crucial aspect of modern military and civilian operations. Although the problem of sustained attention is not new to the military (e.g., observers in "crow's nests" of sailing ships), the problem has been exacerbated by the proliferation of automated systems that relegate the human operator to the role of system monitor. It has also been well established that there are individual differences in performance associated with vigilance (see Davies and Parasuraman, 1982; Berch and Kanter, 1984; Davies, 1985). However, among the several traits that are associated with performance, it is unclear how task conditions influence these trait-performance relations or whether and how traits themselves *jointly* influence performance. Indeed, Berch and Kanter (1984) noted this problem over 20 years ago.

One potential skill that may differentiate good "vigilators" from poor ones is the capacity to cope with the stress and high workload associated with sustained attention. Research has indicated that vigilance tasks impose substantial workload (Warm, Dember and Hancock, 1996), and that operators find these tasks to be stressful (Warm, 1993; Szalma et al., 2004; Warm, Matthews, and Finnomore, this volume). However, individuals who engage in more task or problem-focused

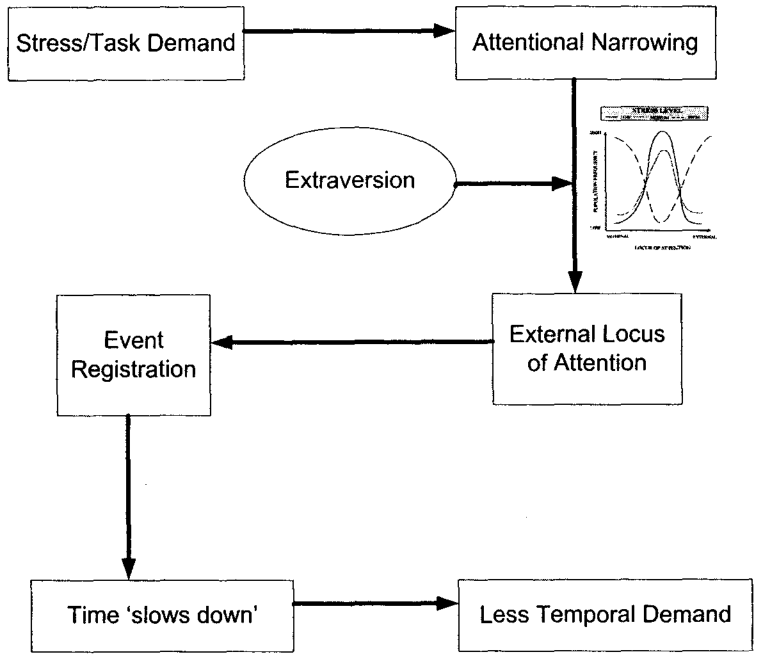


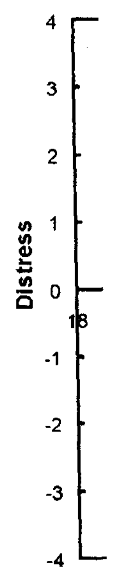
Figure 16.6 Potential mechanism by which extraversion, task characteristics, and environmental demands influence perceived temporal demand

coping under stress (Lazarus, 1991; Lazarus and Folkman, 1984; Matthews and Campbell, 1998) may be able to sustain their attentional capacity longer. Pessimism and optimism may therefore influence the performance, perceived workload, and stress associated with vigilance by influencing task appraisal and coping processes. Thus, Helton et al. (1999) reported that individuals high in pessimism exhibited a steeper vigilance decrement than more optimistic individuals. They also reported that pessimists reported higher levels of stress symptoms. Although efforts to replicate these performance results have been mixed (e.g., Szalma, 2002b; Ganey et al., 2003; Helton et al., 2005; Szalma et al., 2006), other experiments have demonstrated that pessimism is indeed associated with higher levels of stress and less adaptive coping in vigilance (Szalma, 2002b; Ganey et al., 2003; Szalma et al., 2006). One possible reason for these inconsistencies is that the task used in the Helton et al. (1999) experiment was very demanding, employing a very high event rate and a difficult visual discrimination. By contrast, the tasks used by Ganey et al. (2003) and Szalma (2002b), while demanding and of longer duration, involved easier perceptual discriminations. Further, Helton et al. (2005) found a significant relation of optimism to performance only in a low signal salience condition. It is likely that performance differences related to dispositional pessimism and optimism emerge only when the task is sufficiently demanding that substantial coping resources are required, such that the tendencies for pessimists to engage in more maladaptive forms of coping result in the diversion of cognitive resources away from task performance and toward managing negative emotions and dealing with task-irrelevant interference (see Matthews and Campbell, 1998; Matthews et al., 1999, 2002). Note that it is precisely at this point of stress level that theories such as the maximal adaptability model would predict performance failure (Hancock and Warm, 1989; see also Hancock and Szalma, Chapter 1, this volume; Szalma and Hancock, 2005). Further, the diversion of effort away from task demands, although not a problem for relatively undemanding tasks, diverts much needed resources and effort when tasks are demanding (cf. Hockey, 1997). This interpretation of the research on the relation between pessimism/optimism and performance, workload, and stress of vigilance is consistent with the general finding that traits are more strongly associated with effective adaptation when environmental demands (i.e., stress) are high (Matthews, 1997, 1999; Matthews and Zeidner, 2004).

Pessimism and display format Although the evidence described above reveals that those high in pessimism experience stress when engaged in vigilance, these effects are not uniform across all task characteristics. We have already noted that task difficulty and demand (e.g., event rate) may influence whether pessimism is related to performance. It is also the case, however, that display characteristics moderate the relationship between pessimism and task stress. Thus, Szalma (2002a) examined the effect of using different formats of configural displays on the performance, workload, and stress associated with vigilance. Configural displays exploit emergent features (or, in the case of object displays, actual features) by semantically mapping system dynamics to easily perceivable display dynamics, thereby enhancing the salience of changes in the display. These displays can improve performance (see Bennett and Flach, 1992) and may also serve as possible approaches to designing for stress mitigation (Hancock and Szalma, 2003a). Szalma (2002a) reported that a group differences analysis yielded the expected performance enhancement with using configural and object displays and in the case of object displays, this performance enhancement was associated with a reduction in perceived workload. Although pre-post vigil changes in stress state were consistent with previous research, Szalma (2002a) reported that there were no significant effects of display or discrimination type on the stress or coping responses of observers.

However, an individual differences analysis revealed effects of display and pessimism on stress and coping response. Szalma (2002b) reported no significant association between performance and optimism or pessimism, but pessimism significantly predicted perceived workload, changes in pre-post task stress and in choice of coping strategy. Further, the prediction of workload by pessimism was restricted to the task requiring the more demanding discrimination (i.e., when the configurality of the display did not aid performance). Among the subscales of the TLX, it was the perceived performance and frustration scales that showed significant relationships to pessimism, but only with the more difficult discrimination task. Note that these dimensions of workload reflect appraisals of the self (i.e., how the individual perceives his/her response to task demands) rather than appraisals of task demand (e.g., mental demand), consistent with the finding that individuals who are high in Neuroticism (pessimism is correlated with Neuroticism; see Richardson, 1999) tend to engage in more negative thinking regarding their own performance (Matthews, Deary and Whiteman, 2003). With respect to stress, pessimism predicted higher levels of pre-task stress and optimism predicted the opposite trend: lower levels of pre-task stress. Although pessimism and optimism also predicted higher and lower post-task stress, respectively, these associations were not statistically significant with the pre-task states were accounted for in the regression models. These results suggest that the influence of pessimism and optimism effects on stress response to sustained attention may be mediated by their pre-task affective state rather than by any strategic differences in how these individuals process task-related information. However, the relations among these variables are likely dependent upon task parameters, as Helton et al. (1999) reported significant pre-post differences in stress state as a function of pessimism.

Optimism, pessimism, and feedback Another variable that moderates the relation between pessimism and stress response in vigilance is the form in which knowledge of results (KR) is provided in training for vigilance. Szalma et al. (2006) examined the effect on performance, workload, and



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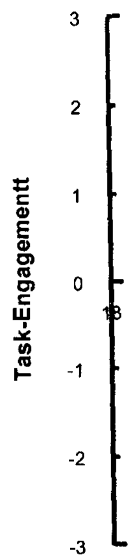

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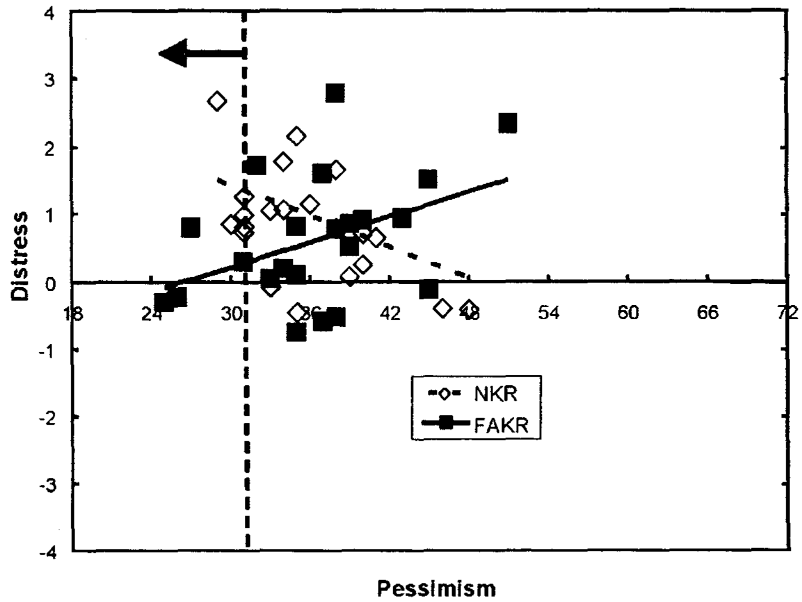


Figure 16.7a Pre-post task distress as a function of pessimism and feedback condition

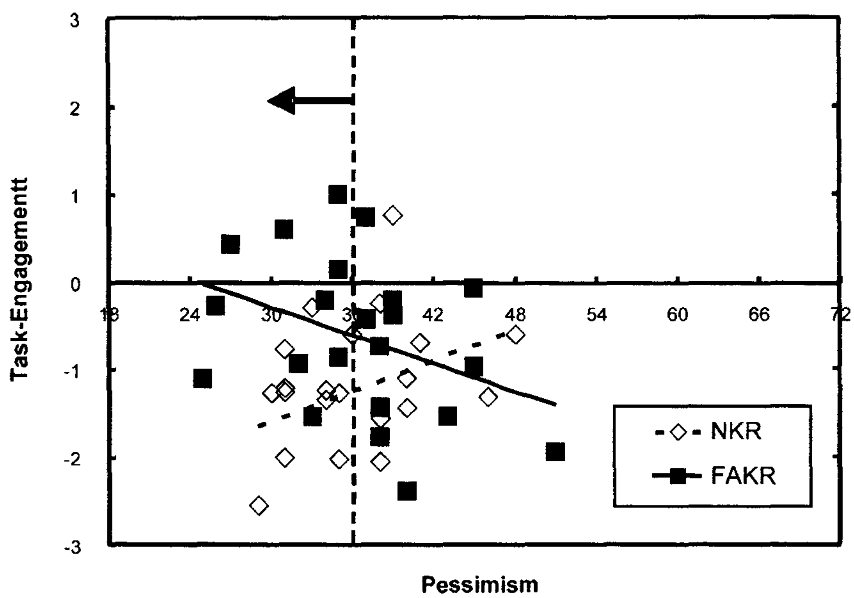


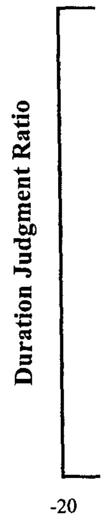
Figure 16.7b Pre-post task distress as a function of pessimism and feedback condition

Note to 16.7a and 16.7b: Dotted line with arrow represents the region of significant differences between the regression lines. NKR = no feedback provided; FAKR = feedback provided regarding false alarms.
Source: Szalma et al., 2006.

stress of providing feedback regarding correct detections, false alarms, misses, or all three forms of KR to observers. In that study, a configural object display was used, and Szalma and his colleagues reported that, at the level of group differences, KR enhanced performance when all three forms of feedback were provided. The individual differences analysis revealed that pessimism did not significantly predict performance, perhaps due to the facilitating effect of an object display on signal salience (Szalma, 2002a). However, pessimism was associated with pre-post task increases in distress and pre-post task decreases in task engagement, but these predictive relationships depended on the form of feedback provided. Thus, false alarm KR reduced the Distress associated with vigilance (presumably by providing information regarding the accuracy of responses), but this benefit was restricted to individuals low in pessimism (see Figure 16.7a). For individuals higher on that trait, false alarm KR did not reduce pre-post task distress. Similarly, false alarm KR also served to increase task-engagement (which reflects motivational and energetic aspects of stress state; see Matthews et al., 2002), but only for individuals low in pessimism (see Figure 16.7b). Pre-post task worry was related to optimism but only weakly to pessimism. However, the relationship between worry and optimism was restricted to the miss-KR training condition. Thus, provision of miss-KR served to reduce pre-post task worry, but only for individuals relatively high in optimism. Note that optimism and pessimism were associated with the stress effects of "negative" feedback (i.e., feedback regarding errors) rather than "positive" feedback (i.e., feedback regarding correct detections). This suggests that pessimists and optimists are differentially sensitive to the valence of feedback in terms of stress response (cf. Gray, 1982; see also Matthews and Gilliland, 1999), although they are able to retain sufficient resources to devote the effort necessary for task performance regardless of their level on these traits.

The role of disposition in shooting performance and time perception

In addition to laboratory studies on attention and monitoring, we have also conducted research on the personality traits associated with performance on firearms training tasks completed under time pressure as part of mandatory field exercises for law enforcement officers (Szalma, Oron-Gilad, and Hancock, 2005; Oron-Gilad et al., 2007; Szalma et al., 2007). No significant association between the five traits and performance in shooting tasks were observed, a finding one would hope to observe in professional police officers. There was also no association of the traits to prospective time estimation of the duration of the more demanding tasks. Consistent with the maximal adaptability model (Hancock and Warm, 1989), there was evidence of a subjective cost to performance in the form of increased perceived workload for more demanding of the tasks, and an increase in stress symptoms pre-post training session (Oron-Gilad et al., 2007). However, these effects varied as a function of officers' personality traits (Szalma et al., 2005, 2007). Specifically, individuals high in Conscientiousness reported greater temporal demand, and individuals higher in emotional stability (neuroticism) reported higher perceived performance ratings. Intellect, which corresponds to the "openness to experience" domain of the Big Five (Goldberg, 1992), also predicted higher ratings of task demand (mental and temporal) as well as effort. However, this relationship was observed only for the most difficult of the shooting tasks performed. Such results accord with studies reviewed above indicating that traits are more likely to be associated with stress response only when the demands of the task are sufficiently high to force the individual to allocate compensatory effort and leave fewer resources available for on-going self-regulatory processes. With respect to stress and coping, Agreeableness was associated with higher post-task engagement, consistent with the generally energetic approach to tasks and compliance associated with individuals high on that trait (Matthews, Deary and Whiteman, 2003). Higher post-task engagement was associated with higher levels of Intellect. Individuals high on this trait tend to



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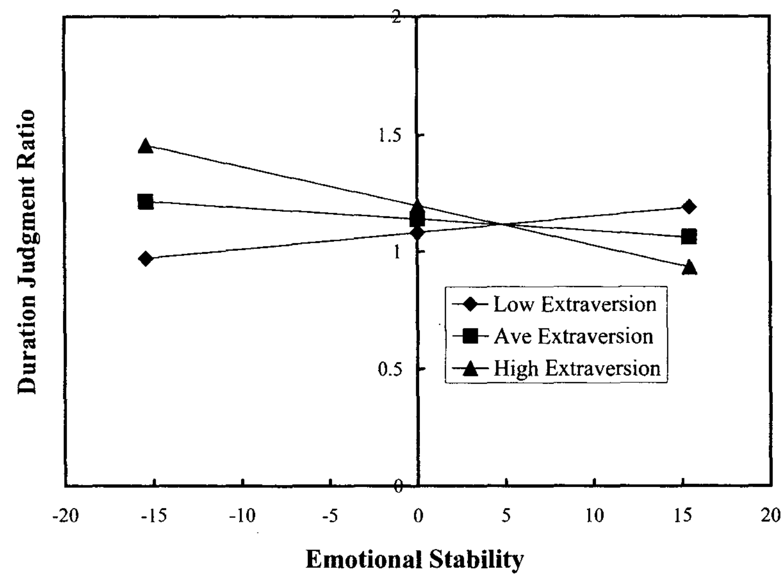


Figure 16.8a Duration judgment ratio (estimated time/clock time) as a function of emotional stability at three levels of extraversion for a challenging firearms task

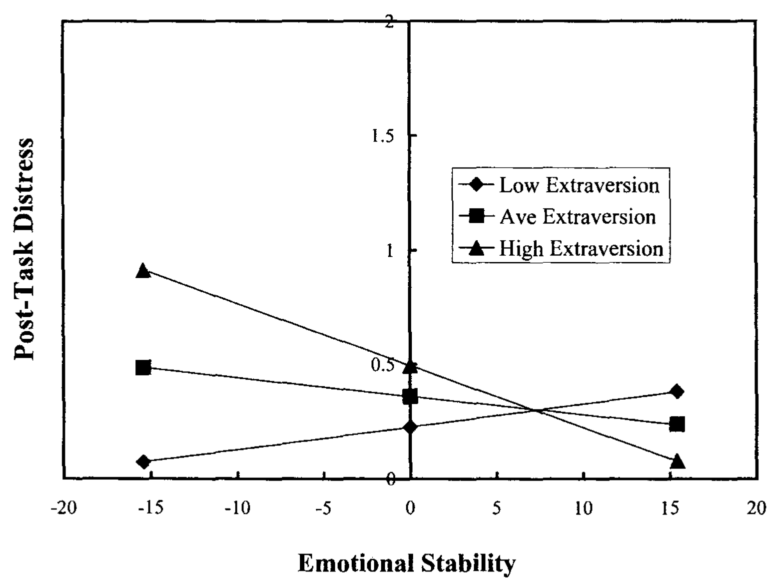


Figure 16.8b Post-task distress as a function of emotional stability at three levels of extraversion

Source: Szalma et al., 2007.

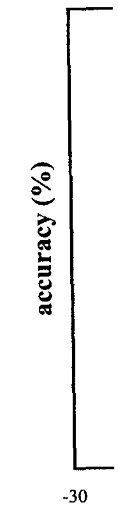
enjoy challenging activities, and this may have made them more engaged in the tasks. Indeed, individuals high in Intellect also reported greater use of task-focused coping skills, consistent with greater engagement in the task.

Joint effects of traits The results described above indicated that traits may affect the workload, stress, and coping with demanding firearms tasks. However, the examination of each trait separately masked more complex interactions with respect to performance and stress state. Indeed, previous research has demonstrated that traits can have joint or "interactive"[2] effects on worker performance evaluations. For instance, Burke and Witt (2002) reported that Intellect "interacts" with Extraversion, Emotional Stability, and Agreeableness in predicting supervisor performance ratings of financial service employees. Similarly, Extraversion and Emotional Stability are known to interact in influencing variables associated with stress such as depression and anxiety (The "neurotic introvert;" Eysenck and Eysenck, 1985), and the influence of the capacity to control one's attention on performing attentional demanding tasks depends on one's level of trait anxiety (Derryberry and Reed, 2002). In the police field study, analysis of joint trait effects revealed that shooting performance and time perception were indeed related to officer traits (Szalma et al., 2007). Thus, extraversion and emotional stability jointly predicted time perception ratings of officers after a demanding shooting task (see Figure 16.8a), such that at low levels of emotional stability individuals high in extraversion judged the task to be significantly longer than those low on extraversion. At higher levels of emotional stability no substantial differences in duration judgment as a function of extraversion were observed. These results were consistent with the hypothesis, based on Hancock and Weaver (2005), that an individual whose attention is externally directed (e.g., extraverts) is more likely to experience a "slowing down" of time. Interestingly, a similar interaction was observed for post-task distress (see Figure 16.8b). That is, among individuals low in emotional stability, those high in extraversion reported greater post-task distress than their cohorts low in extraversion. No such differences were observed at higher levels of emotional stability.

By far the most important variable with respect to interactive effects was Intellect. Recall that no significant associations were observed between shooting accuracy and *individual* traits. However, there was a *joint* prediction by Intellect and Conscientiousness, such that higher levels of Intellect were associated with higher shooting accuracy, but only for individuals high in Conscientiousness (see Figure 16.9a). No such relation was observed for individuals low in Conscientiousness. Note that these effects were restricted to the most difficult task performed by the officers in the training session, consistent with the other findings reviewed in this chapter. Finally, Intellect and Conscientiousness also jointly predicted post task distress, such that at the end of the training session individuals high in conscientiousness reported greater levels of distress, but only for those low in Intellect (see Figure 16.9b). Again, this may indicate that something about those high in Intellect (e.g., perhaps the use of more adaptive coping strategies) serves to protect them from stress symptoms if they are also high in Conscientiousness (and therefore more likely to have allocated substantial effort to task performance).

Intellect and Emotional stability jointly affected time perception on one of the more difficult tasks (see Figure 16.10a). Thus, low emotional stability was associated with greater distortions of time (overestimation), but only for individuals low in Intellect. The same variables jointly predicted pre-task (i.e., pre-training session) Worry, with lower emotional stability associated with greater worry regarding the imminent training activities (Figure 16.10b). However, this pattern of results emerged *only* in individuals who were *low* in Intellect. No such differences were observed at higher levels of Intellect, suggesting that high levels on this trait may serve as a "protective factor" for stress states.

2 The term "interaction" will be used here for convenience and simplicity of discussion. However, it should be remembered that the joint "effect" of measured traits cannot be interpreted in the way that interactions are considered in factorial designs in which participants are assigned at random to experimental conditions.



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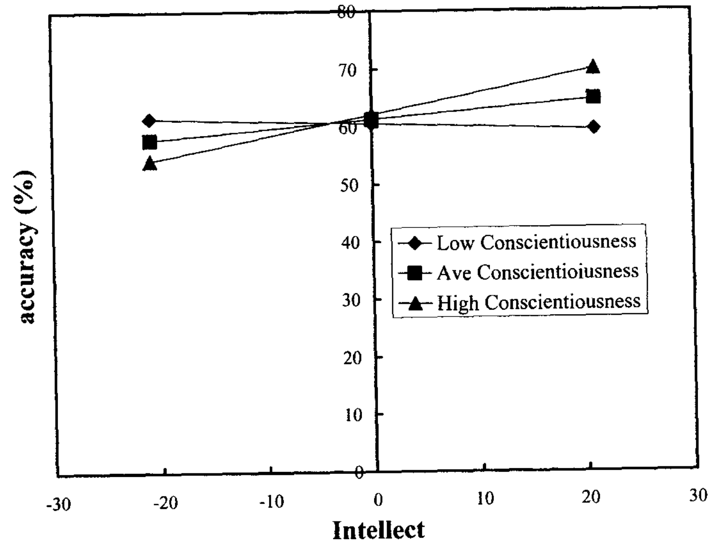

Figure 16.9a Shooting accuracy on a challenging firearms task as a function of intellect at three levels of conscientiousness

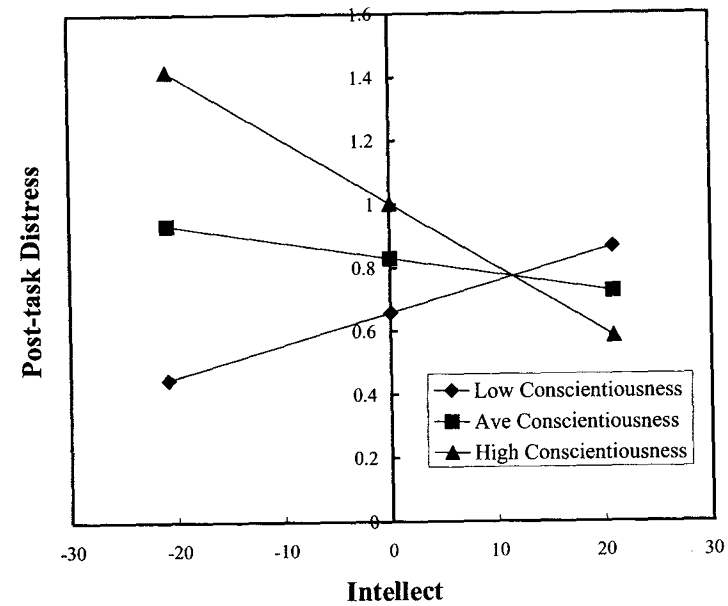

Figure 16.9b Post-task distress as a function of intellect at three levels of conscientiousness
Source: Szalma et al., 2007.

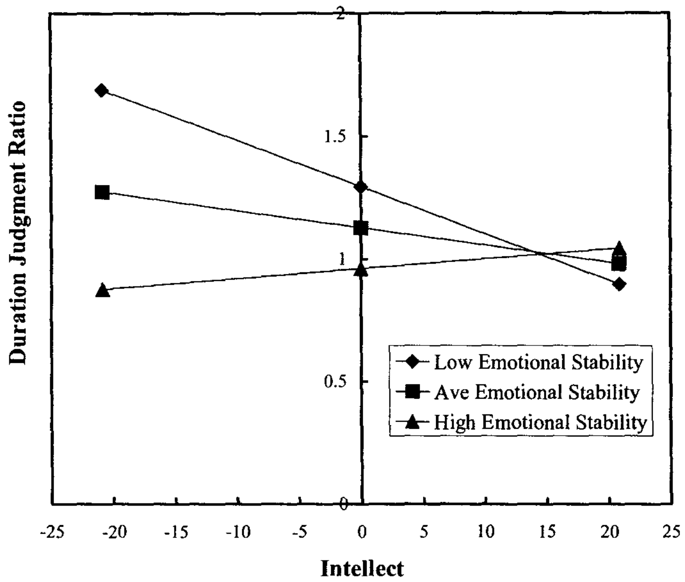

Figure 16.10a Duration judgment ratio (estimated time/clock time) as a function of intellect at three levels of emotional stability for a challenging firearms task

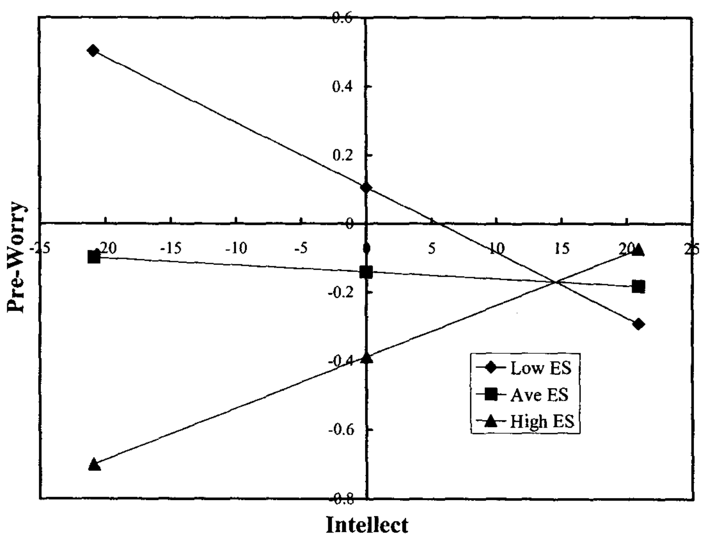

Figure 16.10b Pre-task worry as function of intellect at three levels of emotional stability
Source: Szalma et al., 2007.

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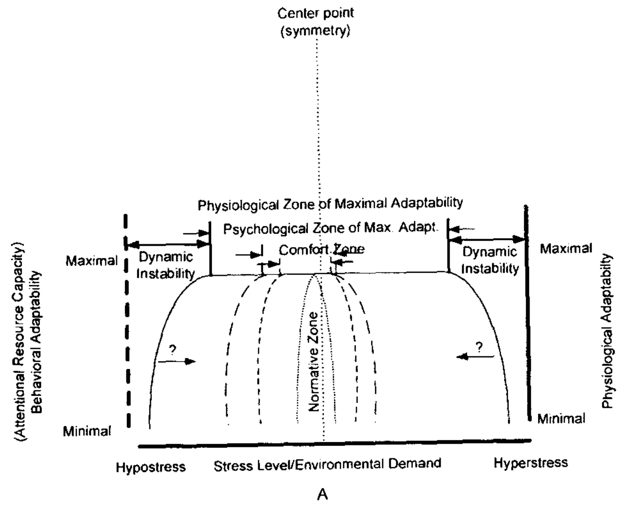

Figure 16.11a The maximal adaptability model incorporating hypothesized adaptive function of individuals low in emotional stability (a similar pattern would be expected for trait anxiety and pessimism)

The vertical line labeled "center point" illustrates the asymmetry in the model introduced by consideration of traits

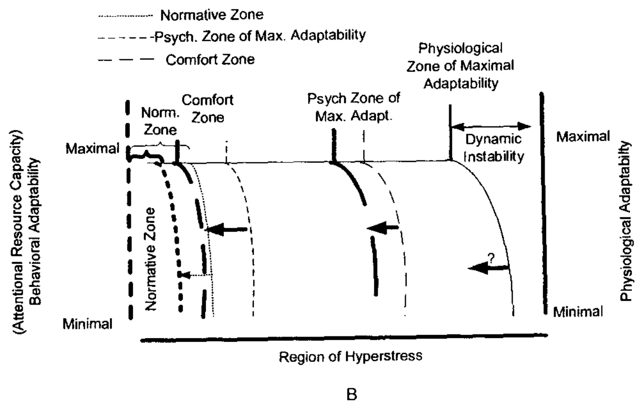

Figure 16.11b Representation of the maximal adaptability model shown in (A) focusing on the hyperstress region

Note that the thin curves are represent "normative" patterns of adaptation, and the thicker curves represent hypothesized adaptive patterns for individuals low in emotional stability (or high in trait anxiety or pessimism). Low emotional stability would be expected to shift the thresholds of failure (the "shoulders" of the functions) lower, such that for these individuals adaptive failure occurs at lower levels of environmental demand. However, the degree of shift is not equivalent for each level of adaptation. Thus, one might expect that the normative and comfort zones to narrow to a greater degree than the zone of psychological (i.e. performance) adaptation.

Incorporation of individual differences into stress theory

As we have noted elsewhere (Szalma and Hancock, forthcoming), because individual differences are a source of influence on adaptation to stress and the allocation of effort and compensatory mechanisms, the maximal adaptability model (Hancock and Warm, 1989) and the compensatory control model (Hockey, 1997) should be extended to include individual differences as an input or component. For the Hancock and Warm (1989) model, it is likely that individual differences will exert their effects in determining the width of the "plateau" of adaptive function and/or the slope of the decline in adaptive response when the threshold or "shoulder" of failure occurs (Szalma and Hancock, forthcoming). For instance, it is likely that individuals lower in emotional stability will reach the thresholds for psychological comfort and, if task demand is sufficiently high, quality of performance earlier than those higher on that trait. Alternatively, an individual who uses adaptive coping strategies may have a tolerance threshold much higher than an individual who uses maladaptive coping (e.g., avoidant coping). An implication of this possibility is that it may be possible to train "expert stress copers" and to adapt such training to the needs of the individual learner, based on his/her affective traits. Figures 16.11a and 16.11b show a possible application of the Hancock and Warm (1989) model to emotional stability (trait anxiety and pessimism would likely show similar patterns to emotional stability).

With respect to the compensatory control model (Hockey, 1997), there are several points at which traits may exert an influence. First, traits may influence both the level and the allocation of effort toward task performance. For instance, individuals low in emotional stability or high in pessimism may prematurely or wrongly conclude that allocating effort to performance will not be useful to achieve success and therefore "give up" and abandon the task. Even in cases where effort is maintained, traits such as pessimism may reduce the efficiency of the effort or action monitors. Thus, as pessimism is associated with maladaptive coping strategies in domains where time pressure is an element (e.g., Helton et al., 1999, cf. Matthews and Zeidner, 2004), it is possible that individuals high on that trait will devote substantial effort to regulating their emotions or avoiding the stress, reducing the amount of resources available to deal with the high task demands. This pattern of responding suggests that improving task skill, including stress coping skills (e.g., see Driskell, Salas, Johnston, and Wollert, this volume), represents a potentially useful approach to mitigating the stress related to performance failures for individuals with traits that are associated with maladaptive responses (Matthews, 1999). The effectiveness of task skills likely manifested in the shooting performance observed in the police field study. Even police officers with lower levels of emotional stability[3] still performed as well as their cohort higher on that trait when the task was a simple one with which they were very familiar. Similarly, the effects of trait on performance, workload, and stress response in laboratory experiments are generally observed only when tasks are relatively difficult. Because the difficulty of a task for any individual is influenced by skill level, stressors are more likely to impair performance of a vulnerable individual (e.g., high anxiety, pessimism in task environments with high time pressure) who lacks adequate skills to cope effectively with the stress. Stated another way, even an anxious, pessimistic person can perform well if he/she is trained so that many elements of task performance require more automatic rather than controlled processing (Schneider and Shiffrin, 1977).

3 Note that "low emotional stability" (alternatively, "high neuroticism") is a relative term. All the officers were in the "normal" range of the emotional stability spectrum, showing no evidence (based on the measure used) of clinical depression or anxiety.

Barriers to theory integration

Ultimately, the ability to integrate theories of personality, stress, and performance will depend on the degree to which the latter can be meaningfully quantified. Specifically, for an individual differences perspective to fully contribute to stress research concepts such as "resources" must be refined. This is a problem in general for stress research (for recent discussions see Hancock and Szalma, 2007; Szalma and Hancock, forthcoming), and ultimately is closely related to the problem of quantifying human information processing (McBride and Schmorrow, 2005). Although there have been substantial efforts to link personality theory with cognitive science and cognitive neuroscience (e.g., see Matthews, 1997a; Ackerman, Kyllonen and Roberts, 1999; Ackerman and Kanfer, 2004; Matthews and Zeidner, 2004), these have yet to be fully integrated into the dominant energetic models of stress and performance discussed in this and other chapters of this volume. For instance, if the base axes of the Hancock and Warm model, which reflect spatial and temporal task elements, could be adequately defined and quantified, investigation of trait-task interactions using the cognitive adaptive framework could be accomplished more precisely with resultant benefits to both theory and practice. Although quantification of these axes is a difficult undertaking, novel approaches to quantifying human information processing are emerging (McBride and Schmorrow, 2005; in particular, see Hancock, Szalma and Oron-Gilad, 2005; Szalma and Hancock, 2005). Integration of these lines of research is crucial if a more complete and accurate model of human performance under stress is to be achieved.

The way forward: Cognitive-adaptive framework, stress, and performance

The cognitive-adaptive model represents integration of theories of personality, emotion, and cognitive science, making it extremely useful for application to the study of human performance under stress. The identification of "trait-cognitive" patternings is a promising approach to understanding how traits influence performance, and corresponds to the "broad band" approach to stress research advocated by Hockey and Hamilton (1983). A successful application that may serve as a guide for future work is the cognitive patterning of extraversion. This was summarized by Matthews (1992, 1997b), who noted that extraverts show superior divided attention, resistance to distraction, and working memory capacity, but are less skilled at sustained attention, or engaging in reflective problem solving. However, the application of this approach to individual differences research has been the exception rather than the rule. Much of individual differences research in human factors and ergonomics focuses on very specific traits (e.g., need for cognition, cognitive failure) applied to a limited number of performance settings. Even at the level of broad traits, most relevant research for understanding performance under stress and the application of human factors principles to mitigate stress, have focused on extraversion and neuroticism. Conscientiousness, Agreeableness, and Openness to Experience have been relatively neglected (Matthews, Deary and Whiteman, 2003). In contrast with the broad band approach advocated by Matthews (1992), the narrow band approach has been applied more often in individual differences research. In this approach, the influence of several traits on one kind of task or information processing is evaluated. Such research is useful in summarizing how trait profiles may be related to a single task, exemplified in the effects of individual differences on vigilance performance (Davies and Parasuraman, 1982; Berch and Kanter, 1984; Davies, 1985). However, this approach renders it more difficult to clearly establish the links between the traits and the cognitive states associated with task performance. In addition, the "profile" established in the narrow band approach is most often distributed across different studies, making theory driven evaluation of the relationship between trait profiles and task performance within a single study relatively difficult, a limitation Berch and Kanter (1984) themselves noted. The assertion here is not that the narrow band approach be completely abandoned, or that the study of very specific traits (e.g., field dependence) should cease. Rather, individual differences research should be organized around a common framework that, when combined with empirical research using the broad band approach, would organize the empirical literature and improve theories of information processing, stress, and performance.

Stress theory and the cognitive-adaptive framework

Although the maximal adaptability model and the compensatory control model are presented and used in stress research, they are actually models of how humans perform activities (i.e., *behave*) and adapt to change. "Stress," as environmental demand, physiological and psychological response, and the transaction between these, is not a discrete state. It is instead a continuous stream of cyclic activity. That is, internal and external demands are always present and fluctuate in intensity, and humans continuously adapt to these at multiple levels of transaction (Matthews, 2001). Hence, stress research should move away from discrete, static approaches (e.g., "exposure vs. non-exposure" to a stressor) and consider change in adaptation *over time*. This is hardly a new idea. For instance, treating human behavior as a "continuous stream" and focusing on change in the flow of behavior was advocated by Atkinson and Birch (1978) with respect to motivation research, and in stress theory by Lazarus and Folkman (1984). Indeed, Lazarus and Folkman (1984) explicitly noted the importance of time in understanding human-environment transactions in their characterization of cognitive appraisals as "largely evaluative, focused on meaning or significance, and [taking] place *continuously* in waking life" (p. 31, emphasis added). Taking this perspective, future research should increase its focus on the changes in cognitive state as a function of *changes* in stress exposure during a performance session (e.g., increases or decrease in noise, time pressure) or *changes* in task demand (e.g., workload transitions; see Huey and Wickens, 1993; and see also Cox-Fuenzalida, Swickert and Hittner, 2004) or task difficulty. This would address the question of how cognitive state and adaptation change when the "stress" fluctuates from one level to another. The need for such an approach has been recognized, with workload transitions being a noteworthy example. Further, changes in cognitive performance and in stress over time have been investigated in experimental paradigms such as vigilance and adaptive automation. Indeed, with the burgeoning field of neuroergonomics the potential for more fine-grained analysis of change in stress state over time is growing rapidly (Hancock and Szalma, 2003b, 2007). What is needed is an extension of this mindset to the inclusion of an individual differences analysis of the person-environment transaction at multiple levels of analysis.

Increased understanding of phenomena as complex as performance under high workload and stress will be facilitated by theories that integrate the models of the cognitive, emotional, and motivational processes with models of stress and performance. Many psychological theories have common constructs (e.g., resources, adaptation, arousal, attention), but they organize them differently within their respective theoretical structures (e.g., resources in Hockey's model *vs.* in the Hancock and Warm model). In addition, many theories use different terms to describe similar processes (e.g., selective/divided attention *vs.* working memory *vs.* short term memory), and the same terms to describe different processes (e.g., knowledge, value, valence, resources, stress). Although these theories are not necessarily in fundamental opposition to one another (e.g., they share common assumptions regarding adaptation and the importance of cognitive resources), this "buzzing confusion" must end if we are to move beyond incremental advances. Individual differences research cannot resolve many of these definitional problems, but analysis of the differences in human characteristics that influence the transaction between environmental characteristics and human cognition, emotion, and motivation can contribute to further elucidation of these elusive constructs by specifying how human characteristics interact with those of the task to influence performance outcomes, particularly when employed in tandem with a neuroergonomics approach (Hancock and Szalma, 2007).

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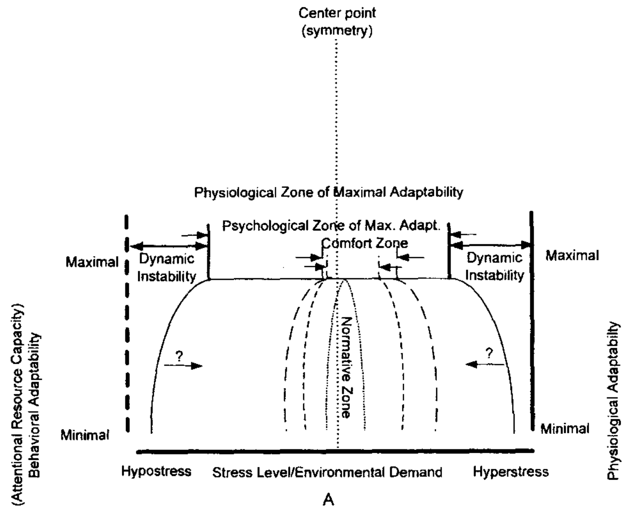

Figure 16.12a The maximal adaptability model incorporating hypothesized adaptive function of individuals high in extraversion

The vertical line labeled "center point" illustrates the asymmetry in the model introduced by consideration of traits.

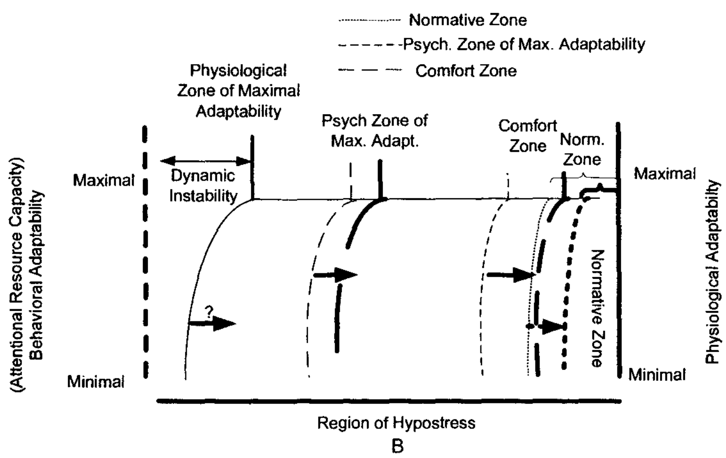

Figure 16.12b Representation of the maximal adaptability model shown in (A) focusing on the hypostress region

Note that the thin curves represent "normative" patterns of adaptation, and the thicker curves represent hypothesized adaptive patterns for individuals high in extraversion. High extraversion would be expected to shift the thresholds of failure (the "shoulders" of the functions) such that for these individuals adaptive failure occurs at less extreme levels of hypostress or under stimulation. However, the degree of shift is not equivalent for each level of adaptation. Thus, one might expect that the normative and comfort zones to narrow to a greater degree than the zone of psychological (i.e. performance) adaptation.

An example: Extraversion

To demonstrate potential ways of integrating the cognitive-adaptive framework to stress theory, we consider Extraversion and Anxiety because these traits have been studied more extensively than others (Matthews, Deary and Whiteman, 2003). Recall that the cognitive patterning of extraversion consists of faster responding, less accuracy, larger working memory capacity and more attentional resources, and better divided attention (Matthews, 1992, 1999). This permits them to maintain performance levels (adaptive plateau) in the presence of noxious or distracting stimuli with fewer resources devoted to the supervisory controller for maintaining performance levels (i.e., less compensatory effort required). Further, as they have larger working memory and resource capacities they can tolerate higher levels of demand than those low in extraversion. These would have the effect of shifting the edges of adaptation failures of comfort and performance further out (i.e., at higher levels of stress; see Figure 16.12a). Although extraverts and introverts may have similar skill levels for a cognitive task, and therefore shift to the higher level control loop (i.e., automaticity levels, cf. Hockey, 1997), the strategic decisions made by the supervisory controller, which can select from multiple options to deal with the increased demand, will likely differ as a function of traits and the nature of the environmental demands. For high stress (overload) conditions the extraverts would have the advantage because the effort "budget" is larger and therefore more effort can be allocated without additional cost to functional state. In addition, the efficiency of the controller and the effort monitor are likely to be higher for extraverts and those low in Neuroticism/ Anxiety, the former due to larger resource capacities and the latter due to fewer resources allocated to managing negative affective states.

However, a different scenario emerges if the environmental demands are characterized by hypostress (underload) where there is minimal task or time pressure and, in some cases, reflective problem solving may be required. In these circumstances, individuals lower in extraversion have the advantage, because the amount of working memory/resource capacity available for task performance is functionally increased by the increase in time allowed for information processing. Extraverts, however, might be more prone to boredom for lack of stimulation, and therefore have to devote efforts to compensate for the unpleasant state such environments induce in them. Thus, for *hypostress* the shoulder of failure occurs at less extreme levels of hypostress for those high in extraversion and earlier for those high in that trait (see Figure 16.12b). Note that this introduces an asymmetry in the maximal adaptability model (see Figure 16.12a), as a function of the trait and associated cognitive patternings. In addition, the size of the adaptive "zones" will be different as a function of trait differences. Thus, in overarousing situations, low extraversion would likely be associated with a smaller difference (relative to extraverts) between the thresholds of the normative and comfort zones. The reverse pattern would be expected for the hypostress region. In other words, the size of the normative, comfort, and psychological zones of adaptability likely vary as a function of traits, and, in the case of extraversion (and also Neuroticism/Anxiety; see Figures 16.11a and 16.11b) be asymmetric around the center of the comfort zone. Whether such differences extend to the physiological threshold will likely depend on the physiological system in question. In general, one would expect that the magnitude of the effect of individual differences in affective traits on adaptation would decline as one moved to either extreme of stress level. Similarly, there are likely points of task load that will overwhelm the resource capacity of the supervisory controller for most individuals, regardless of trait. In addition, as the evidence reviewed in this chapter suggests, at low levels of task demand traits are not likely to exert as strong an influence. Note that low demand does not necessarily mean that the individual is in the hypostress region. Low demand *can* lead to hypostress if that state is aversive to the individual (e.g., boredom), but it does not deterministically lead to such a state. It depends on the appraisals of the demands (Lazarus and Folkman, 1984), which itself is influenced by cognitive and affective traits.

The above considerations suggest that if the task is relatively difficult (e.g., a difficult perceptual discrimination under conditions of low signal salience such as camouflaged objects), individuals high in extraversion might find sustained attention tasks more stressful and report higher levels of workload. Introverts, who are better adapted for such environments, would have more capacity to devote to the monitoring task, because extraverts would have to devote resources to managing the aversive situation (i.e., devote more compensatory effort and be higher in "strain" levels). The evidence that exists for both long duration and short duration detection tasks does not uniformly support the above hypothesis (e.g., Rose et al., 2002; Thropp et al., 2004), but to completely test this conception requires systematic manipulation of task demands that push the individual closer to the thresholds of adaptive failure (increases the strain on the supervisory control loop). From the cognitive-adaptive framework perspective, the task demand must be manipulated so that the tasks vary in the skills required and the effect of task parameters on knowledge structures (i.e., motivational and emotional states; self-efficacy, etc). Further, changes in adaptation should be examined as a function of time. Although performance may be preserved regardless of an individual's trait characteristics, failures in subjective comfort (perceived workload and stress) may emerge earlier for individuals low extraversion (and perhaps low in emotional stability as well) for tasks that impose multiple demands or are performed in the context of time pressure. Similarly, individuals high in extraversion may reach the threshold of failure in subjective comfort earlier for tasks associated with hypostress (e.g., vigilance).

Note that this example has focused on Extraversion. The same logic can be applied to Neuroticism/Anxiety or to any other trait (e.g., pessimism/optimism). The situation is further complicated when one considers interactions among these traits. Thus, the actual form of the extended-inverted U would be a resultant of combinations of functions (vectors) based on trait profiles. These are important issues for further research, because although the analyses are complex, this complexity is what exists in real-world stressful environments.[4] However, to fully exploit this approach by applying it to traits such as pessimism, Conscientiousness, Agreeableness, or Openness to experience (Intellect), the cognitive patterning of these traits needs to be empirically established as it has been for Extraversion (Matthews, 1992, 1999).

Applications to human factors and ergonomics

Design principles and guidelines

The cognitive-adaptive framework provides a strong foundation for theory and research on which to empirically investigate individual differences in human performance, but there has been limited application of theory and research on trait-performance relationships to problems in human factors and ergonomics (i.e., interface and training design principles and guidelines). What has been investigated are often very specific traits for very specific domains, making derivation of general theory and design guidelines difficult. In real world environments individuals perform tasks requiring multiple cognitive processes that need to be well supported by interface and training design in order to ensure protection of performance in stressful circumstances. Hence, what is needed is integration of the cognitive perspective on personality with the design principles of human

4 I am reminded of one of Hancock's aphorisms with respect to psychology: "There are the hard sciences, and then there are the *difficult* sciences." The problem of individual differences in performance certainly provides evidence supporting that statement!

factors and task taxonomies that can be derived from human factors and ergonomic methodologies (e.g., cognitive task analysis). That this has been relatively neglected is understandable, given the theoretical difficulties and empirical inconsistencies that have historically plagued individual differences research. However, we are presented with real-world problems here and now, and it is time to take what theory and research we have and derive general guidelines or principles for design, so that those creating human-machine interfaces can design displays that take different "trait-cognitive" patterns into account. Establishing such patterns can also be applied to the design of training regimens, for instance by placing extra emphasis on those aspects of task performance or environmental conditions in which individuals with specific trait-cognitive patterns are most vulnerable. Note that these suggestions do not replace current practices in training and interface design, but rather *augment* and *extend* them to account for differences across the individuals who are the ultimate "customers" for interface design.

Applying the theories discussed here, it is clear that interfaces and training should be designed to facilitate effective (i.e., adaptive) responses and protect performance when problems occur in environments to which the person is not dispositionally well adapted. For instance, because individuals low in Trait Anxiety and high in Extraversion tend to respond well to fast paced environments, they should receive additional training in coping with low demand environments (the moments of boredom), while those (relatively) high in Neuroticism and/or low in Extraversion might benefit from stress training for the time pressured environments (moments of terror). Such an intervention should not replace existing training procedures, and it is not the case that those high in Extraversion and low in Neuroticism/Trait Anxiety do not need training for stressful conditions. Rather, it may be that additional or more intensive training should be employed for conditions to which individual trainees may not be dispositionally well-adapted.

In regard to display design, individuals high in Extraversion/low in Neuroticism/Trait Anxiety should have displays that adapt to their state as a function of changing demands. Using adaptive automation as an example (see Parasuraman and Hancock, Chapter 3, this volume), during the "moments of boredom" extraverts might need tasks that engage them so as not to strain their limited resources on coping with the relatively aversive underload. By contrast, those low in Extraversion and/or high in Neuroticism/Trait Anxiety may need higher levels of automation (see Oron-Gilad et al., 2005) and displays with easily perceivable elements (Hancock and Szalma, 2003a) when task demands increase dramatically over short time epochs (moments of terror). Note that *it is not the case that one set of trait profiles is* "good" *and others* "bad," for task performance, a typical bias among practitioners who use measures of affective traits primarily as a selection or job placement tool. Rather, different profiles are associated with better adaptive responses in different environments (see Matthews, 1997b, 1999; Matthews, Deary and Whiteman, 2003). One implication of this is that it may be advisable to create teams with diversity in trait profiles so that team members can aid one another as operational conditions change. For instance, it may be useful to include both optimists and pessimists on a team so that their different strengths and capacities can complement one another (Dember, 2002).

Future research

Taken together, the results of the field and laboratory studies reveal that whether affective traits influence performance, workload, and stress depend in part on the characteristics of the tasks themselves as well as the profile of operator traits. Thus, the finding of relatively weak correlations between traits and performance (e.g., Barrick and Mount, 1991; Barrick, Mount and Judge, 2001) may be due to masking by 1) variability in task and environmental characteristics across studies, and 2) complex interactions among traits, cognitive states, and the characteristics of the environment, especially the task structure itself. Further exacerbating the latter problem is the relatively limited number of studies examining the interactions among multiple traits and task characteristics. Hence, an area clearly in need of further research is in examination of "joint" or "interactive" effects of multiple traits on information processing and performance. Even under uncontrolled conditions of a field study such effects emerge, and they should be examined systematically in the laboratory to determine which information processing capacities are influenced by joint trait interactions (e.g., working memory capacity, attentional control, spatial or verbal processing skills, etc). Further, the effect of different levels of task demand, and the nature of those demands, needs to be evaluated with respect to combinations of traits.

Conclusions

In this chapter the case for an individual differences approach to understanding performance under stress was presented, with examples of studies conducted both in the laboratory and in the field. The problems are complex, which makes developing a comprehensive theoretical model difficult. A framework exists, however, that can be integrated with established stress theory. Theoretical integration can point the way toward systematic research to enhance our understanding of the multiple factors that control performance and how to exploit them to the benefit of those who operate under highly stressful conditions. This chapter illustrates an initial attempt at such integration.

Pursuing integrative research of the nature described above will yield positive results, but it will take the efforts of many and does not represent a "magic bullet" solution. It might therefore be tempting for some individuals to revert to applications of individual differences research to the personnel selection approach by simply assigning individuals to tasks and environments to which they are best suited. This can be useful to some degree, but there are reasons for avoiding over reliance. First, in some domains there are limitations in "human capital," (e.g., the armed forces) and selection based on affective traits may not be practical. Second, even in domains where selection is possible and is currently standard practice (e.g., law enforcement), it is difficult to assign individuals to environments to which they are best adapted because the environments change frequently. These changing circumstances should be incorporated into the design and operation of tasks and interfaces, and consideration of affective traits and their relation to performance can facilitate these efforts. Finally, in many real-world situations the environment does not monolithically support adaptation for individuals with particular trait profiles. For instance, based on the evidence, it seems reasonable to assume that in a combat situation the low Neuroticism/ Anxiety combined with Extraversion would generally perform better at the cognitively demanding tasks required of leaders in those situations. However, due to heightened awareness for threat, individuals high in Anxiety and low in Extraversion might be more attuned to changes in the environment during a routine patrol, potentially facilitating their capacity to detect IEDs. Note that the implication here is not that stable extraverts are poor at detecting threat or that neurotic introverts are poor decision makers in combat. Rather, it is argued that because individuals with different traits are differentially well-adapted to different environments, we should exploit those differences through training and interface design. If we are to prevail in the cognitively dominant World War IV (Scales, 2006), it is crucial that we utilize all our psychological tools ranging from the perceptual and cognitive to the personality traits of military personnel to interface and training design. Considering individual differences affords an avenue toward making such design a force multiplier that maximizes performance and survivability of our military and homeland security personnel.

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