Cognitive Resilience

the SpunkyGidget Rogue Report

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Cognitive resilience is a construct that has recently attracted the attention of researchers but is not yet well understood. The research literature in this area addresses a loose association of related concepts such as hardiness, stress vulnerability, coping style, protective factors, and self-efficacy (Bandura, 2001; Florian, Mikulincer, & Taubman, 1995; Kobasa, 1979; Kobasa, 1982; Kobasa & Puccetti, 1983; Lazarus & Folkman, 1984; Nowack, 1989; Rhodewalt & Zone, 1989). A constellation of factors have been shown to contribute to cognitive resilience. These factors include cognitive appraisal, locus of control, perception of predictability and control, dispositional optimism, learning, experience/expertise, affectivity, motivation, effort, social support systems, and other individual difference characteristics (Bandura, 2001; Kobasa, 1979; Lazarus, 1966; Lazarus, 1990; Lazarus & Folkman, 1984; Seligman, 1998; Seligman & Csikszentmihalyi, 2000).

In general, cognitive resilience describes the capacity to overcome the negative effects of setbacks and associated stress on cognitive function or performance. As such, cognitive resilience can be understood to manifest as a continuum of functionality or behavioral outcome. On one end of the continuum, cognitive processes are overwhelmed by stress and consequently might be ineffective. On the other end of the continuum, there are few or no negative effects of stress on cognitive performance. Within and between these two extremes, individual differences may interact to enhance or diminish resilience to the effects of stress on various specific cognitive processes under different conditions, settings, and levels of demand. The focus of most of this research has been on the effects of stressful conditions on cognitive performance. Although the evidence is presently quite limited, cognitive resilience can be thought of in another, quite different way. That is, cognition itself can influence or moderate adverse effects of stress on other types of behavior (Gilbertson et al., 2006). We will have more to say about results of this sort later in this chapter.

The cognitive resilience literature has historically focused on specific contexts in which some individuals succumb to stress while others are better able to withstand or overcome it. For example, some children are able to overcome negative life circumstances (e.g., poverty, poor health, violence, lack of family support) that can be devastating to other children (Cesarone, 1999; Comer, 1984; Garmezy, 1991; Kumpfer, 1999; Luthar, Cicchetti, & Becker, 2000; O'Neal, 1999). These and related studies of resilience have informed our understanding of individual vulnerability to mental health problems such as depression, post-traumatic stress disorder (PTSD), and the onset of schizophrenia (Bonanno, Field, Kovavecic, & Kaltman, 2002; King, King, Foy, Keane, & Fairbanks, 1999; Robbins, 2005; Robinson & Alloy, 2003). Resilience may also help to explain patterns of cognitive decline associated with normal aging and other degenerative processes (DeFrias, Dixon, & Backman, 2003; Mackinnon, Christensen, Hofer, Korten, & Jorm, 2003; Seeman, Lusignolo, Berkman, & Albert, 2001; Wilson, deLeon, Barnes, Schneider, Bienias, Evans, & Bennett, 2002).

There is also an extensive body of research devoted to the study of human performance under stress. Studies in this area reveal and emphasize primarily negative effects of stress on cognition (Bourne & Yaroush, 2003; Driskell, Mullen, Johnson, Hughes, & Batchelor, 1992; Driskell & Salas, 1996; Hancock & Desmond, 2001;

Staal, 2004; Stokes & Kite, 1994). Unfortunately, beyond addressing training and experience levels, the human performance literature generally fails to address individual differences that may explain or promote resilience to stress.

In the following sections, we provide a brief overview of how stress affects the primary cognitive processes of attention, memory, and judgment/decision making. Although this initial discussion will be general in concept and limited in scope, it will provide the basis for consideration of specific moderating factors that promote cognitive resilience. Finally, we address how these factors might be applied to practical purpose in military and other operational environments.

What is Stress?

There are two traditional models of psychological stress. A *stimulus-based model* treats stress as a function of external influence (e.g., demanding workload, heat/cold, time constraint). Critics of the stimulus-based model argue that it ignores individual differences, does not adequately evaluate contextual circumstances, and neglects entirely the role of emotion (Stokes & Kite, 1994). By contrast, a *response-based model* holds that stress is a composite of response patterns (behavioral, cognitive, and affective) that result from exposure to a given stressor.

More recently, a third approach has emerged to conceptualize stress more broadly as an interaction between the individual and his or her environment. *Transactional model*s of stress emphasize the role of the individual in appraising a situation and shaping responses to it. For the purpose of this chapter, we view stress as the interaction between three transactional elements: perceived demand, ability to cope, and perceived importance of coping with the demand (McGrath, 1976).

Stress and Human Performance

Human performance under stress depends on multiple factors related to the individual performer and to specific attributes of the situation in which he or she must perform. As noted earlier, research in cognitive science reveals a continuum of outcome, ranging from no effect on cognitive processes to extreme dysfunction (Bourne & Yaroush, 2002; Driskell & Salas, 1996; Hancock & Desmond, 2001; Staal, 2004). However, effects of stress on human performance in general – and on cognition in particular -- can be very difficult to predict at the individual level. The intensity of a particular stressor or condition might be increased without coincident or measurable effect on the performance of one individual, while the same increase might be associated with dramatic degradation in the performance of another. Whether by disposition or experience or both, some individuals are simply better able or equipped than others are to handle stress. It may be possible to mitigate vulnerability to stress by experience and training, although there is little research available yet to guide the development of resilience training per se.

Quantitatively, it has long been known that stress effects on human performance generally follow an inverted U-shaped function. According to the Yerkes-Dodson law (Yerkes & Dodson, 1908) and a considerable body of evidence consistent with it, increasing amounts of stress (arousal) are associated initially with improved performance. However, at some point, stress level reaches an optimal level, beyond which performance will degrade as stress continues to increase. This performance pattern is well established, but does not tell the whole story and has limited explanatory value for a number of reasons documented elsewhere (see Hancock, 2002). We suggest that for the purpose of understanding stress effects on cognition, the usefulness of the Yerkes-Dodson framework can be improved by a more detailed consideration of specific effects or *stress states* (Bourne & Yaroush, 2002) at and between the extremes of the inverted "U" curve. Figure 1 depicts the Yerkes-Dodson inverted "U" function and its relationship to stress states identified specifically as facilitation, optimization, mobilization, degradation, "choking," and panic.

(insert Figure 1 about here)

As noted, initial increases in stress are typically associated with improvement in performance. This phenomenon is known as *facilitation*, and it may be related to positive effects of increased arousal on cognitive function. For example, Chappelow (1988) conducted an analysis of aircrew performance errors and found that performance was improved in a slightly more stressful environment. A certain amount of stress-related arousal may be conducive to specific cognitive functions such as attention and memory.

At some point for any given task and individual, performance under stress will reach its *optimal* level. Beyond that optimal level, additional stress typically exerts a detrimental effect on performance. However, if a performer is sufficiently motivated, he or she may be able to maintain or improve performance beyond the optimal level. This phenomenon is attributed to *mobilization* of mental effort, which is invoked when performance level is recognized as insufficient for success. Indeed, mobilization of mental effort will tend to maintain or improve performance at any level of stress. Effort mobilization plays a prominent role in Kahneman's classical analysis of attention

(Kahneman, 1973) and has received empirical support in research conducted by Kahneman and others (e.g., Doerner & Pfeifer, 1993; Hockey, 1997).

At some point as stress continues to increase, there begins to occur an unavoidable *degradation* in performance. At this point, the performer will find it increasingly difficult or impossible to perform successfully. Ordinarily, performance will degrade gradually (or gracefully; see Norman & Bobrow, 1975). However, extreme stress may produce a catastrophic degradation that manifests as "*choking"* or *panic*. These phenomena have been demonstrated experimentally by Lehner, Seyed-Solorforough, O'Connor, Sak, and Mullin (1997), who observed among other things that when human operators were subjected to extreme stress (e.g., extreme time pressure), they abandoned procedures they had been trained to follow and reverted instead to more familiar, more intuitive procedures that produced inferior results.

Strictly quantitative formulations such as the Yerkes-Dodson law fail to capture the more qualitative character of phenomena such as facilitation, optimization, mobilization, degradation, "choking" and panic. By expanding our consideration to include these qualitative phenomena, we can interpret more fully the empirical effects of stress on primary cognitive functions such as attention, memory, and judgment and decision making. These effects are reviewed in the next section as a critical first step toward identifying factors, processes, and relationships that may serve to mitigate the negative effects of stress, and thus promote cognitive resilience.

Stress Effects on Cognition

Attention

Because attention is a critical gateway to other cognitive processes, it is among the most widely studied phenomena in cognitive science. Although the full scope of information processing begins with pre-attentive, preparatory functions such as orientation and pattern recognition (see Sokolov, 1963; Rohrbaugh, 1984; Duckworth, Bargh, Gracia & Chaiken, 2002), these early processes are largely unaffected by ambient stress and are immune to effects of resource sharing (see *cognitive resources*, discussion below). Effects of stress and task-related demands are generally not observed until formal attentive and higher-order cognitive processes are called into play.

In general, studies of stress and attention converge on findings first reported by Easterbrook (1959) concerning the relationship between motivation, drive, arousal, and cue utilization (range of informational cues attended). Extensive research in this area has shown that individuals under stress tend to reduce their use of peripherally relevant information. These individuals tend instead to centralize or limit their focus of attention to stimuli they perceive to be most important or most relevant to a main or primary task. This *tunneling hypothesis* has been echoed by numerous other investigators (Baron, 1986; Broadbent, 1958, 1971; Bundesen, 1990; Bursill, 1958; Cohen, 1980; Combs & Taylor, 1952; Cowan, 1999; Davis, 1948; Driskell, Salas, & Johnston, 1999; Hockey, 1970; Hockey, 1978; Hockey & Hamilton, 1970; James, 1890; Murata, 2004; Pamperin & Wickens, 1987; Salas, Driskell, & Hughes, 1996; Stokes, Wickens, & Kite, 1990; Vroom, 1964; Wickens, 1984; Williams, Tonymon, & Anderson, 1990; Zhang & Wickens, 1990). Research has also demonstrated that the tunneling of attention may be helpful or harmful to performance, depending on the nature of the task at hand and the circumstances under which it must be performed. For example, when peripheral cues are irrelevant to an important primary task, it may be helpful to ignore them. However, if peripheral cues are ignored when they might otherwise bear relevance to an important task, performance on that task may suffer.

Several theories have been proposed to explain why stress affects attention as it does. Chajut and Algom (2003) posit that stress depletes attentional resources and thus reduces the bandwidth of attention such that peripheral information is neglected and attentional selectivity is improved. When we speak of *cognitive resources*, we refer to a theoretical reservoir of mental capacity that can be drawn from in order to meet the demands of various cognitive tasks. Although many previous investigators have sought to define this concept precisely, empirical research in the area has remained vague and ill-defined (Szalma & Hancock, 2002). Wickens (1984) has suggested that the term, “resources,” can be considered synonymous with a number of other common terms such as capacity, attention, and effort. Kahneman (1973) is frequently cited as the first to propose a limited-capacity resource model, although Norman and Bobrow (1975) are typically credited with coining the term. Kahneman suggested that there exists a limited pool of mental resources that can be divided across tasks. Kinsbourne and Hicks (1978) argued that resources can be construed as competing for actual cerebral space, although there is no solid empirical evidence for this claim. Others have related resource management and consumption to the brain’s metabolism of glucoproteins and changes in blood flow (Gur & Reivich, 1980; Sokoloff, 1975), but again supporting evidence is minimal.

A second explanatory framework is the *capacity-resource theory* (Chajut & Algom, 2003), which suggests that when stress occurs, attention is narrowed to the direction of whatever information is most proximal, accessible, or automatic (e.g., primed cues) without regard to its task relevance. Working from a capacity-resource model, a number of workload studies have focused on the siphoning of attentional resources by task-irrelevant activities during driving (Hughes & Cole, 1986; Matthews & Desmond, 1995; Matthews, Sparkes, & Bygraves, 1996; Metzger & Parasuraman, 2001; Recarte & Nunes, 2000; 2003; Renge, 1980; Suzuki, Nakamura, & Ogasawara, 1966). Research in this area indicates that automobile drivers tend to pay a significant amount of attention (perhaps as much as 50%) to activities or objects that are unrelated to driving. Evidence from a series of studies by Strayer and his colleagues (e.g., Strayer & Drews, 2004; Strayer, Drews, & Johnston, 2003), using a driving simulator, shows that drivers who are involved in cell phone conversations have slower brake response times and are more likely to miss roadside sign information and traffic signals than are drivers who are not so engaged. Indeed, driving performance during cell phone use is sometimes inferior to that accomplished while under the influence of alcohol. Horrey, Wickens, and Consalus (2006) extended these findings to other in-vehicle technologies such as navigational devices or traffic, road, and vehicle status information.

Strayer et al. attributed the adverse effects of cell phone use to a shift of attention away from visual input toward auditory information that is necessary to comprehend phone conversations, whereas Horrey et al. emphasized the interfering effects of expanding attentional bandwidth. Both ideas are consistent with an interpretation of stress effects based on capacity resource theory.

A third theoretical framework proposed to explain stress effects on attention is known as *thought suppression* (Chajut & Algom, 2003), which holds that tunneling effects are due to competition between consciously-controlled attention and an unconscious search for “to-be-suppressed” material. The supposed competitive effect of secondary monitoring is believed to be the result of additional demands placed on attentional resources when an individual becomes sensitized to information he or she should ignore (e.g., “whatever you do, don’t look down”). This effect may be amplified under stress and produce hypersensitivity toward task-irrelevant information (Wegner, 1994; Wenzlaff & Wegner, 2000).

The study of attentional decrement under stress has focused heavily on specific attentional processes, most especially sustained attention (vigilance). The type of stress associated with vigilance tasks is often related to task demands and to boredom associated with those demands (Frankenhaueser, Nordheden, Myrsten, & Post, 1971; Galinsky, Rosa, Warm, & Dember, 1993; Hancock & Warm, 1989; Hovanitz, Chin, & Warm, 1989; Mackworth, 1948; Scerbo, 2001). Empirical studies of vigilance usually apply stress in the form of fatigue (e.g., due to prolonged work shifts or sleep deprivation; Baranski, Gil, McLellan, Moroz, Buguet, & Radomski, 2002), although other stress conditions such as noise, temperature, time pressure, and workload have also been applied (Kjellberg, 1990; Pepler, 1958; Van Galen & van Huygevoort, 2000; Wickens, Stokes, Barnett, & Hyman, 1991). Similar cognitive performance decrements have been found for a variety of task types and measures, including serial response times, logical reasoning, visual comparison, mathematical problem solving, vigilance, and multi-tasking (Samel, Wegmann, Vejvoda, Drescher, Gundel, Manzey, & Wensel, 1997; Wilkinson, 1964; Williams, Lubin, & Goodnow, 1959). Interestingly, some studies have also shown that the direct effects of stress can be modulated by individual differences and by psychological processes that mobilize resources such as motivation and effort. Unfortunately, these studies are few in number and have failed to address stress modulation effects in detail.

Attention researchers have also observed that well-learned tasks are associated with fewer lapses in attention. Well-learned skills are performed more "automatically" in the sense that they require fewer mental resources and less deliberate or conscious control of attention. Presumably, then, more cognitive resources are left available to support the performance of other or additional tasks (Beilock, Carr, MacMahon, & Starkes, 2002).

The observations reported above will be considered again later in this chapter, with specific emphasis on their potential utility and relevance to cognitive resilience.

Memory

The study of memory involves two important construct distinctions that are essential to defining the character and role of memory in any given situation. First, researchers draw a distinction between *explicit* and *implicit* memory to describe the extent to which task performance is consciously and deliberately controlled (Schacter,1989). On learning a new task or skill set, an individual usually must think through each step of the task in a deliberate manner and explicitly encode new information into memory (a necessary precondition for automatic task performance; Logan & Klapp, 1991; Zbrodoff & Logan, 1968). As learning proceeds, task performance requires less deliberation, less step-by-step attention and less conscious information processing. With practice and repetition, task-related responses eventually become more automatic in the sense that they require little or no conscious control (Shiffrin & Schneider, 1977). Task performance improves as task-related responses become more fluid and less effortful. At this point, task-relevant information and knowledge retrieval is said to be implicit (Reber, 1989; Schacter, 1987).

Another important distinction is based on a temporal continuum from the remote past (retrospective *long-term memory*; Atkinson & Shiffrin, 1968) to the present or near present (*short-term memory*, immediate or working memory; Atkinson & Shiffrin, 1968; Baddeley, 1986; 1992) and into the future (*prospective memory*; Brandimonte, Einstein, & McDaniel, 1996; Winograd, 1988). Long-term memory describes a repository for facts and skills acquired in the past. Short-term memory refers to an assortment of facts and skills that are relevant to the current or recent focus of attention. Prospective memory preserves intentions or reminders of actions that must be executed at some point in the future. Stress and other variables may exert selective effects on these different types of memory.

In general, stress provokes a shift of attention to the here-and-now, and thus can introduce potential consequent degradation of performance on tasks that involve either retrospective or prospective memory (see Healy & Bourne, 2005). There is little empirical evidence concerning stress effects on long-term retrospective memory in particular, but recent studies suggest that stress due to distraction may have specific adverse effects on short-term memory (Larsen & Baddeley, 2003; Neath, Farley, & Surprenant, 2003). Other studies have demonstrated that tests of prospective memory are particularly sensitive to extraneous or secondary task demands (Einstein, McDaniel, Williford, Pagan, & Dismukes, 2003). These results, although limited, are consistent with a *memory constriction hypothesis*, which holds that the time span from which knowledge can easily be retrieved and used in a given context will tend to shrink with increasing levels of stress (e.g., Berntsen, 2002). The consequent neglect of facts or procedures held in long-term memory, and/or failure to execute required responses at appointed future times, might explain many of the performance errors that tend to occur under stress. This reasoning is also consistent with attention tunneling effects commonly observed under stress (see, e.g., Easterbrook, 1959). Although empirical evidence is currently somewhat limited as to broad time-based stress effects on memory, this type of theoretical framework may yet prove useful as a guide to future research.

General stress effects on memory. A variety of stressful conditions influence the way in which memory functions. For example, Gomes, Martinho-Pimenta, and Castelo-Branco (1999) showed a significant negative impact of stressful noise on immediate verbal memory. Fowler, Prlic, and Brabant (1994) reported a similar effect of hypoxia on the executive function of working memory. Finally, Parker, Bahrick, Fivush, and Johnson (2006) observed a full-range Yerkes-Dodson function on memory for events during a major hurricane, with moderate stress associated with best recall. George Mandler (1979) was one of the first cognitive psychologists to speculate theoretically about the effects of stress on memory, arguing that stress creates cognitive system “noise,” which in turn competes with task-related demands on limited cognitive (conscious) resources. According to this view, memory processes that rely upon conscious elaboration of current sensory input and relatively new memory representations (explicit memory) should be especially sensitive to stress. Van Gemmert and Van Galen (1997) share Mandler's view (1979), arguing that stress-related noise in the cognitive system results either in reduced sensitivity to task-related sources of information or in less exacting motor movements.

Mandler's theoretical framework is logically consistent with the memory constriction (tunneling) hypothesis. It is reasonable to suppose that when attention is focused to the here-and-now, the likely result will be greater reliance upon explicit (deliberate, conscious) memory processes, which are in turn relatively more vulnerable to stress effects than are automatic (implicit) memory processes. However, this possibility raises the question of whether short-term memory is more or less resilient to stress, and why. It is certainly possible that short-term memory is inherently more vulnerable to degradation by stress and that tunneling of attention and memory serve to mitigate this vulnerability. Additional research is needed to examine this and other possible interpretations of stress effects on memory.

Van Overschelde and Healy (2001) have demonstrated that stress can be provoked by information overload during a learning task, but that negative effects can be mitigated by elucidating connections between new facts (i.e., new information to be learned under stress) and information that already resides in long-term memory. The general principle illustrated here is that the acquisition and retention of new information and associations is facilitated by linkage to existing knowledge. This strategy is based on a theory of *long-term working memory* (Ericsson & Kintsch, 1995) which postulates that information held in long-term memory can be temporally activated or primed for easy access by task-related cues from short-term memory. This proposed mechanism has been useful as a means to explain text comprehension and expert-level performance on memory span tasks, as well as resilience to information overload.

A different view on the role of working memory can be found in the study of individuals who suffer from math anxiety (Ashcraft, 2002; see also Ashcraft & Kirk, 2001), where it has been proposed that high math anxiety (susceptibility to stress) leads to reduced working memory capacity. When the working memory capacity of non-anxious subjects is limited by added task demands, they show performance decrements that are similar to those observed in high math-anxious subjects. Ashcraft (2002) concludes that stress tends generally to reduce working memory capacity and that any task which involves explicit learning or memory processes should thus be especially vulnerable to stress.

Matthews (1997) has argued that intrusive thoughts and other "worries" occupy space in working memory, and thereby interfere with the performance of tasks that rely upon working memory. Matthews' research has also shown that "worries," daily hassles, and/or intrusive thoughts tend to occupy more space in working memory among high-anxious than among low-anxious subjects (see also Dudke & Stoebber, 2001). Matthews, Emo, Funke, Zeidner, Roberts, Costa, and Schulze (2006) demonstrated that measures of emotional intelligence (EI) and the stress coping strategies that EI entails do relate positively to subjective feelings of concern and worry. However, Matthews et al. were unable to show any significant impact of EI on performance under stress in tasks that required little or no working memory. In a review of the literature, Miyake and Shah (1999) identified emotion, stress, and anxiety as major modulating factors in memory but noted the need for additional research to address how these variables affect particular aspects of memory (especially working memory) such as memory maintenance, executive control, and content.

Context and state dependency. It is well known that memory is context-dependent (e.g., Johnson, Hashtroudi, & Lindsay, 1993) in that memory task performance is typically better when it is tested in a context identical or very similar to the context in which the task was originally learned. Few studies of stress effects on memory have taken into account the potentially confounding influence of context dependency. One of very few exceptions is a study conducted by Thompson, Williams, L'Esperance, and Cornelius (2001), which directly examined context effects by testing the recall of experienced skydivers who learned word lists while in the air (stressful context) or on the ground (less stressful context) prior to participating in a skydiving event. The skydivers' recall was poor in air-learning conditions, regardless of the context in which they were later tested for recall. That is, there was no context effect on memory when learning took place under stress. But when lists were learned on land, later recall was better when it was also tested on land, demonstrating a clear effect of context dependency.

The researchers also tested other subjects in less stressful conditions. Instead of participating in a skydiving event, these subjects merely watched a skydiving video. In this case, recall was better when contexts matched, regardless of stress condition. Thompson et al. thus proposed that under extremely emotionally arousing circumstances (e.g., preparing in the air for a sky dive), environmental cues (context) are less likely to be encoded or linked to newly acquired information and thus are unavailable to serve as cues to later retrieval under less emotional circumstances. Put more simply, the generally strong context and state dependency effects on memory might be overridden under extremely stressful conditions.

The findings reported by Thompson et al. call attention to the need for similar research in operational paradigms. This type of research may improve our understanding of resilient behavior and task performance in occupations and settings that expose individuals to emotional stress during initial training and/or subsequent recall of trained information. One implication is that individuals who experience less extreme emotional responses to stress might also demonstrate more persistent (spared) context dependency effects on memory. If so, context-dependent recall under stress might be useful as a “marker” of cognitive resilience.

Judgment and Decision Making

Although judgment and decision making can be viewed as processes or as outcomes – or as one (decision making) the result of the other (judgment) – they are more typically combined (JDM) as an end state which culminates from attention and memory processes. Broadbent (1979) observed that JDM is largely dependent on the perceived probability of possible outcomes. Building on Broadbent’s work, Gigerenzer and Selten (2001) suggested that decision makers rely on a number of heuristics ranging from the simple to the complex. They theorized that human beings are equipped with an adaptive toolbox that contains a variety of different strategies. Accordingly, when faced with the need to make a decision, we are able to employ the most adaptive heuristic available (Gigerenzer, Haffrage, & Kleinbolting, 1991; Gigerenzer & Selten, 2001).

JDM can be degraded by a wide variety of stressors, including noise (Rotton, Olszewski, Charleton, & Soler 1978), fatigue (Soetens, Hueting, & Wauters, 1992), fear (Yamamoto, 1984), interruption (Speier, Valacich & Vessey, 1999), and time pressure (Ben Zur &

Breznitz, 1981; Stokes, Kemper, & Marsh, 1992; Wickens, Stokes, Barnett, & Hyman, 1991; Zakay & Wooler, 1984). Wickens, Stokes, Barnett, and Hyman (1991) examined the effects of time pressure on decision making in aircraft pilots. Building on the earlier work of Broadbent (1971) and Hockey (1983), these authors identified three main effects of stress on JDM: a reduction in cue sampling, a reduction in the resource-limited capacity of working memory and, when time was limited, a speed-accuracy trade-off in performance outcome.

In general, when human subjects are under stress, they become less flexible to alternative JDM strategies (Broder, 2000; 2003; Dougherty & Hunter, 2003; Janis, Defares, & Grossman, 1983; Janis & Mann, 1977; Keinan, 1987; Streufert & Streufert, 1981; Walton & McKersie, 1965; Wright, 1974). Stressed subjects also tend to persist with a particular problem-solving method or strategy even after it fails to be useful (Cohen, 1952; Staw, Sandelands, & Dutton, 1981). These effects seem clear enough, but it remains uncertain exactly what aspects or processes of JDM are degraded, and why. Janis and Mann (1977) were among the first to observe that stress can lead to *hypervigilance*, defined as a state of disorganized and haphazard attentional processing. Janis and Mann proposed a *decision-conflict theory* in which hypervigilance provokes frantic search, rapid attentional shifting, and a reduction in the number and quality of considered alternatives. Hypervigilance thus degrades JDM and, in its extreme, may lead to “choking” or panic (see below; see also Baradell & Klein, 1993; Janis, Defares, & Grossman, 1983; Keinan, 1987).

Although it is generally true that extreme emotional responses to stress interfere with information processing, it is also the case that a manageable negative emotional response might help to sustain JDM under stressful conditions. Sinclair and Mark (1995) explored the effects of mood state on judgment accuracy and found that when individuals experienced a positive mood state, they tended to make less effortful, less detail-oriented, and fewer correct decisions. By contrast, negative and neutral mood states tended to enlist greater effort; decisions made in these conditions were more detailed, more systematic, and more often correct. Therefore, to the extent that a state of stress invokes a manageable level of negative emotion, it may facilitate greater effort and detailed attention, leading in turn to more accurate judgment and improved decision making.

As noted above, good JDM may depend to a large extent on the ability to consider and use alternative heuristics. Support for this idea comes from individual and team performance research. Team studies identify strategy shifting (e.g., from explicit to implicit coordination) as critical to effective team performance (Entin & Serfaty, 1990; Entin, Serfaty, & Dekert, 1994; Entin, Serfaty, Entin, & Dekert, 1993; Serfaty, Entin, & Johnston, 1998). Bowers, Asberg, Milham, Burke, Priest, and Salas (2002) have also observed this to be true for team performance under stressful time and mental workload conditions. Orasanu (1990) reported similar findings for aircrew performance. Entin and Serfaty (1999) have suggested that teams tend to draw upon shared mental models of situation and task. Shared mental models may facilitate team members' ability to shift from explicit to implicit strategies, thereby reducing the mental resource costs incurred by explicit strategies. In effect, teams may respond to cognitive stress much as individuals do and thus be more or less resilient to it for similar reasons.

Human operators may also respond and adapt to stress by shedding or simplifying task demands (Rothstein & Markowitz, 1982). For example, Davis (1948) studied the effects of fatigue and continuous flying operations on pilots. He observed that over time, pilots reduced their attention to peripheral instrumentation and limited their visual scanning to focus primarily on instruments directly relevant to the central task of flying. Bursill (1958) replicated these findings on laboratory tasks. More recently, Raby and Wickens (1990) examined aeronautical decision making in an experimental setting and found that when pilots became task-saturated and stressed, they reduced their own workload by dropping tasks in reverse order of criticality. (It is worthwhile to note that judgment and decision making processes were necessarily involved in making this adjustment.) Sperandio (1971) examined task simplification strategies employed by air traffic controllers and found that they tend to regulate their workload by strategy shifting. When air traffic controllers found themselves under increased traffic load conditions, they tended to reduce the volume of information they provided to each aircrew, eventually reducing it to the minimum amount of information required for safe operations. Sperandio concluded that controllers economized their workload by reducing the amount of redundant and/or non-essential information they themselves might have to process.

The ability to prune or simplify task demands in strategic manner is an adaptive skill in most circumstances. This ability enhances cognitive resiliency by task prioritization and organization, the positive effect of which is an improved economy of resource mobilization. There is evidence to suggest that strategic shedding and task prioritization can be learned and improved by training (e.g., Gopher, 1992; Gopher, Weil, & Bareket, 1994). Effective training of this type may be invaluable to improve JDM in potentially stressful settings. However, it is also important to recognize that adjustment strategies may themselves draw upon already strained cognitive resources and thus may be difficult or impossible to achieve under conditions that impose a very high level of workload or extreme stress.

Summary

Taken together, documented effects of stress on attention, memory, and JDM suggest that effective cognitive performance depends heavily upon the extent to which cognitive resources can be preserved and/or managed. Resource management appears to be directly related to the state of stress experienced by the performer. When cognitive resources are strained or depleted by stress or workload, performance (attention, memory, JDM) is degraded. By contrast, when resources are effectively managed, spared, or mobilized, performance is preserved or facilitated. Training and experience can play a critical role to the extent that well-learned tasks can be performed less deliberately, placing fewer demands on cognitive resources.

Research also indicates that strategy shifting and economizing workload (by reduction or task simplification) can be effective means to mitigate the potentially negative effects of stress on cognitive task performance. These adjustments may help to sustain resource capacity by reducing the need for attention to and processing of redundant or non-essential information. This type of resource management seems to happen logically and effectively at first, but under extremely stressful conditions the resource management process itself may impose additional limitations on performance.

Cognitive Resilience: Moderators, Factors, and Strategies

Studies of psychological resilience have identified a number of moderating variables, protective factors, and behavioral strategies that appear to promote resilience to stress. Here, we address findings of particular relevance to cognitive resilience.

Cognitive Appraisal

Research has provided consistent support for the notion that cognitive evaluation of threat and/or perceived control are influenced by the subjective experience of stress and, conversely, that positive evaluations may offer some level of protection from stress. The basis for this idea is not new. Lazarus (1966) was among the first to observe that when human subjects viewed a situation as negative or threatening, they experienced psychological stress as a direct result of their own negative appraisal (Lazarus, 1990; Lazarus & Folkman, 1984).

The works of many other researchers and theorists suggest that anxiety exerts an important influence on cognitive appraisal. In particular, high-trait and high-state anxious individuals demonstrate an attentional bias toward threatening stimuli (Beck, 1976; MacLeod & Matthews, 1988). Bower (1981) proposes a *network theory* which holds that emotional states prompt the activation of mood-congruent memory representations and consequent selective processing of available information. Taken together, these and a number of other related works support the notion that anxious individuals are more likely to attend and negatively appraise emotionally threatening stimuli (Broadbent & Broadbent, 1988; Calvo & Castillo, 2001; Mogg, Bradley, & Hallowell, 1994; Williams, Watts, MacLeod, & Mathews, 1988).

Relatedly, the work of Wofford and colleagues indicates that low-trait anxious individuals are relatively less vulnerable to negative effects of stress on cognition than are their high-trait anxious counterparts (Wofford, 2001; Wofford & Goodwin, 2002; Wofford, Goodwin, & Daly, 1999). Not surprisingly, negative attitude has been linked to reduced resilience and increased risk for depression following exposure to stressful events (Abela & Alessadro, 2002). Thus, it is reasonable to consider that interventions to reduce anxiety and to support positive emotional orientation may also facilitate positive cognitive appraisal, reduce negative effects of stress on cognition, and promote cognitive resilience.

In addition to its role in emotion and attitude, cognitive appraisal may play a key role in the mobilization of cognitive resources. That is, one's appraisal of a particular stressor or situation might exert a direct impact on one's preparation or will to direct attention to it, and to allocate mental resources to meet the challenge. There are no empirical data currently available to support this notion, but it is reasonable to expect that situations which are perceived as very important, challenging, or threatening would tend to attract the most attention and inspire the most determined preparation and/or allocation of cognitive resources. This is an area that invites additional research with particular attention as to whether resource allocation under stress is deliberate (conscious) or involuntary.

Disposition and Coping

Dispositional optimism is a psychological concept that has received increasing scientific attention in recent years. The "positive psychology" movement has advanced constructs such as optimism, explanatory style, and self-efficacy theories to the forefront of behavioral science research (Bandura, 2001; Seligman, 1998; Seligman & Csikszentmihalyi, 2000). These constructs emphasize the importance of dispositional viewpoint and outlook as factors that exert a significant influence on psychological health. There is a growing body of evidence to support the belief that individuals who are predisposed to optimism enjoy a number of benefits to their well-being, including better overall health and less susceptibility to depression (Seligman, 1998). Similar findings have been reported in studies of self-efficacy (the belief that one has the power to positively influence one’s own circumstances). For example, perceived self-efficacy has been associated with reduced anxiety and increased perceived control over a variety of stressors (Endler, Speer, Johnson, & Flett, 2001).

Although optimism and self-efficacy surely represent the combined effects of emotion and cognition, we need not disentangle these effects in order to recognize their potential joint benefits. To the extent that optimism and self-efficacy represent or encourage positive cognitive appraisal, these dispositional tendencies may also provide some measurable basis for the promotion and prediction of cognitive resilience.

Zakowski, Hall, Cousino-Klein, and Baum (2001) found that coping strategies tend to be congruent with situation appraisal. That is, one’s approach to coping with a stressful situation will tend to reflect one’s own appraisal of the situation itself. Positive appraisals are more often associated with positive outcome and negative appraisals with less successful outcome. Positive appraisal appears to mediate subjective outcome (e.g., self-reported measures of feeling better) as well as objective outcome (e.g., scored task performance). When individuals view an event in positive (but realistic) terms, they tend to cope more effectively, enjoy positive feelings, and experience greater confidence (Janis, 1983; Skinner & Brewer, 2002).

Finally, there is a robust literature examining the extent to which so-called “hardy” individuals respond to stress. *Hardiness* describes an assortment of dispositional characteristics including a strong sense of self and self-efficacy, an internal locus of control (Rotter, 1954), and the perspective that life has meaning and purpose (Kobasa, 1979). In general, hardy individuals are better able to perform well under stress (Westman, 1990) and are less likely to suffer stress-related illnesses (Kobasa, 1979; Kobasa & Puccetti, 1983; Pengilly & Dowd, 2000). Research also indicates that hardy individuals are more likely to engage in solution-focused problem solving strategies, while less hardy individuals tend toward avoidant and emotion-focused coping strategies (Pollock, 1989; Williams, Wiebe, & Smith, 1992).

Predictability and Control

An important outcome of cognitive appraisal is the extent to which stressors are perceived as predictable or controllable. Perceived control and predictability are directly related to subjective distress and cognitive performance. When a situation or stressor is perceived as within one's control, it tends to provoke less subjective stress (Lazarus, 1966). For example, it has been shown that the psychological stress associated with the threat of electric shock can be reduced when an individual perceives control over stimulus intensity, timing, frequency, or termination (Bowers, 1968).

Individuals who perceive themselves as being able to exert some form of control over a stressful stimulus report less anticipatory anxiety (Champion, 1950; Houston, 1972) and demonstrate a corresponding decrease in physiological arousal (Geer, Davidson, & Gatchel, 1970; Szpiler & Epstein, 1976). Control also facilitates prediction. Predictable stimuli – even those that may be threatening – are perceived as less aversive than similar but unpredictable stressors. This effect can be measured by subjective report and by physiological markers (Badia & Culbertson, 1970; Baum & Paulus, 1987; Bell & Greene, 1982; Burger & Arkin, 1980; D'Amato & Gumenik, 1970; Epstein, 1982; Evans & Jacobs, 1982; Monat, Averill, & Lazarus, 1972; Weinberg & Levine, 1980).

Experience and Expertise

The highest standards of cognitive performance are often necessitated by demanding and/or high-risk situations where the consequences of failure may be severe or even catastrophic.

Individuals who work in such settings know well that training and experience are critical to job performance and may even be essential to survival. For example, it is for good reason that aircraft pilots are judged and qualified on the basis of the number of hours they spend in training and in flight. In the cockpit, good decision-making strategies and outcomes are supported by experience and familiarity (Klein & Thordsen, 1991; Stokes, Kemper, & Marsh, 1992; Wiggins & O'Hare, 1995; Shafto & Coley, 2003; Doane, Woo Sohn, & Jodlowski, 2004). Similar findings have been reported for automobile drivers (Lansdown, 2001), firefighters (Klein, 1989; Klein & Klinger, 1991; Taynor, Crandall, & Wiggins, 1987), air traffic controllers (Hutton, Thordsen, & Mogford, 1997), and parachutists (Burke, 1980; Doane, Woo Sohn, & Jodlowski, 2004; MacDonald & Lubac, 1982; Stokes, 1995). In general, individuals who have more experience (experts) attend and process task-relevant information more efficiently and with better results than do individuals with lesser experience (novices). When the stakes are high, expertise may literally make the difference between life and death (Kornovich, 1992; Li, Baker, Grabowski, & Rebok, 2001; Stokes, 1995).

Recent evidence (Gilbertson et al., 2006) shows that experience is aided and abetted by cognitive skill. In this study, soldiers who scored high on tests of cognitive ability were found to be less vulnerable to the development of combat-related post-traumatic stress disorder (PTSD). Thus, beyond the question of how stress affects cognition, it must also be considered that cognitive ability or skill might exert a protective or mitigating effect against the lasting negative psychological impact of stress.

The Presence of Others

The social psychology literature refers to “social facilitation” and “social impairment” to describe positive (facilitation) or negative (impairment) effects of performing in the presence of others. In general, the presence of others tends to exert a facilitative effect on the performance of simple or well-learned tasks while it tends to impair performance on complex, novel, or poorly learned tasks (Allport, Antonis, & Reynolds, 1972; Beilock & Carr, 2001; Beilock, Carr, MacMahon, & Starkes, 2002; Carver & Scheier, 1981; Katz & Epstein, 1991). These findings have interesting implications for cognitive resiliency, specifically with respect to training, complex tasks and systems, human-machine interaction and augmented cognition. For instance, much has been written about using computer-aided technologies to enhance performance through the reduction of task complexity and the introduction of in-the-moment performance feedback (Cooke, 2005; Nicholson, Lackey, Arnold, & Scott, 2005).

Training for Extreme Stress States

As noted earlier, under extremely stressful conditions, human performance degradation can be catastrophic. "*Choking"* is a term commonly used to describe severe performance degradation that may occur as an extreme response to stress (i.e., "choking under pressure"). This extreme response is characterized by an unintentional and paradoxical transition away from well-learned, highly practiced, essentially automatic action toward more deliberate, time consuming, and less effective strategies. When an otherwise highly skilled individual reverts to conscious deliberation to meet each requirement of an otherwise familiar task, he or she loses the ability to generate fluid and efficient results. Response time is increased as each aspect of the task is approached with cautious reference to explicit memories that may not have been accessed for quite some time. In lay terms, this phenomenon is sometimes described as "over-thinking" or "paralysis by analysis."

Recent research suggests that it might be possible to inoculate individuals against the adverse influence of extreme stress. Inoculation techniques involve pre-exposure to stress and training under conditions that incorporate stressful contexts. In one of a very few laboratory studies to address this phenomenon, Beilock and Carr (2001) observed the performance of golfers who had been trained to putt while under audience observation, while performing a distraction task, or in quiet solitude without distraction. When subsequently tested under low-pressure conditions, no performance differences were found among golfers who had been trained under the three different conditions. However, in high-pressure conditions – when a large monetary prize hung in the balance -- golfers who had been trained in the presence of an audience significantly out-performed their counterparts in other training conditions and in fact exceeded their own training performance. The authors (see also Beilock, Carr, MacMahon, & Starkes, 2002) argued that training in an environment in which one is forced to attend to performance (self-focus) from the outset can immunize the performer against negative effects of pressure on later performance. Put simply, training scenarios can be designed to anticipate stress on performance, to avoid “choking,” and to promote resilience.

More recently, Beilock and colleagues have reported somewhat different findings from a study of cognitive task performance. Beilock, Kulp, Holt, and Carr (2004; see also Beilock & Carr, 2005) examined problem-solving performance on familiar (highly-practiced) vs. unfamiliar (infrequently practiced) mathematical problems. In this paradigm, pressure adversely affected performance only on unfamiliar mathematical problems. Beilock et al. concluded that skilled individuals are far less likely to “choke” under pressure when performing cognitive (vs. sensory-motor/coordination) tasks, and further that when “choking” does occur during a cognitive task, the effect is likely attributable to a reduction in working or immediate memory capacity rather than to the invocation of explicit memories (see also Ashcraft, 2002).

Sports literature, history, and folklore contain numerous examples of “choking” due to heightened self-consciousness or stress. Relatively recent examples include Greg Norman's collapse in the final round of the Masters' Golf Tournament in 1996 and Jana Novatna's last-set loss to Steffi Graf at Wimbledon in 1993. However, as noted above, the effects of stress are likely to be different for different types of skills, and in particular for cognitive skills that require involvement of conscious working memory even for highly-developed skills and well-learned tasks. What is needed is a taxonomy that can help to clarify if, when, and how various resources and processes are required for particular skills. Such a taxonomy would help to predict when and how stress might adversely affect performance on specific types of tasks, in what circumstances "choking" might be more or less likely to occur, and when or how it might be possible to reduce the probability of "choking" (i.e., improve resilience) through training or other interventions.

Panic is qualitatively different from "choking" and usually results in even more severe performance degradation. Panic is associated with primitive behavior and maladaptive automatic thinking (Katz &

Epstein, 1991). Rather than “over-thinking” the stressful situation, a panicked person essentially stops thinking altogether and is inclined instead to react in the most basic possible way to escape or avoid the situation entirely. Sport coaches sometimes refer to panic as “brain lock.” Explicit memories become inaccessible. Short-term memory seems to cease functioning. The panicked individual responds in an unskilled way, reverts to primal instincts, or simply fails to respond at all. At best, the panicked individual will focus on a single aspect of the environment, usually to the neglect of information that might resolve or eliminate the stressful condition. Although the panicked individual’s exclusive goal is to survive, his or her performance becomes functionally maladaptive and may in fact make survival less likely (Katz & Epstein, 1991).

Conditions of panic are virtually impossible to re-create in the laboratory. Further, it is not at all clear how pre-exposure or training to mitigate panic might be accomplished. Most of what we know about stress-induced panic comes from case histories and self-reports by athletes and others who have experienced panic in real-world settings. For example, sky divers typically carry two parachutes and are well-trained to release the secondary chute immediately if the primary chute fails to open. Nonetheless, accidents sometimes do occur when sky divers panic and find themselves unable to perform as trained. Langewiesche (1998) documents other poignant accounts of panic as experienced by aircraft pilots.

Clearly, panic is a state one should try to avoid if one wishes to survive an emergency situation. There is obvious value in efforts to develop training strategies and scenarios that may improve preparation in ways that minimize the likelihood of panic. To this end, it may be helpful to train individuals to recognize early symptoms of panic and to offer strategies to prevent its full onset. Unfortunately, at the time of this writing, little or no known progress has been made toward the development of effective panic mitigation procedures.

Summary

Thus far, behavioral researchers have identified several variables which appear consistently to mitigate negative effects of stress on cognition. These include specific individual traits or tendencies (positive appraisal, optimism, expertise) as well as task or situational attributes (predictability and control, the presence of others). It is likely that these are but a few of the many variables that will ultimately be identified as bearing direct or indirect influence upon human cognitive resilience to stress.

Although cognitive task performance under stress seems to depend heavily upon the effective preservation, allocation, or management of cognitive resources, it cannot be assumed that this is the only mechanism by which moderators of cognitive resilience must act. Moreover, there are different strategies (e.g., tunneling, workload reduction, strategy shifting) by which cognitive resource management can be achieved or maintained. Thus, researchers should seek to explain how and when specific moderating variables exert their effects.

The identification of predictive moderators also implies a need to better understand at what point along the theoretical “inverted U” curve specific moderating variables come into play. There is no reason to assume that all moderators of cognitive resilience exert relevant or measurable effects at all times during a stressful task or experience. For example, it may well be the case that a given trait or state variable is specifically conducive to improved cognitive performance by enhanced mobilization, while another is specifically linked to panic deterrence.

Finally, there is the question of which, if any moderating variables might be achieved or improved by training or experience. Effective training strategies would be especially valuable to prevent “choking” or panic in response to extreme stress. There is a pressing need for research in this area to determine how existing and new information about cognitive resilience might be put to practical use in real-world operational environments.

Military Applications and Other Considerations

There are several areas of military activity in which cognitive resilience can play a significant role to enhance performance. These include training, personnel selection/assessment, operational performance, and human operator interface with weapons platforms and related systems. Each of these areas has been addressed quite extensively in the military scientific literature and elsewhere in this volume. Here, we offer a brief review of military needs and activities as they relate specifically to cognition, stress, and resilience. We further consider how resilience might be promoted by anticipating specifically relevant cognitive processes and identifying appropriate potential moderators of stress effects in each case. For example, Table 1 summarizes potential areas of application for the various moderators of cognitive resilience discussed above.

Insert Table 1 about here.

Training and Preparation

The U.S. military's primary business is to fight and win our nation's wars. Crudely put, warfighters are trained to kill people, break things, and support their "brothers in arms" and allies who do the same. By the very nature of their work, soldiers, sailors, airmen, and Marines are placed in harm's way and are asked to perform tasks that demand a high degree of stress resiliency that is rarely needed in the course of ordinary civilian life. Even when warfighters are not directly involved in combat, they must be prepared to endure a variety of extreme physical, psychological, and environmental stressors. For those who experience combat, resilience to stress is critical. The U.S. military selects men and women who, they believe, stand the greatest chance of performing well under the most extremely stressful circumstances conceivable. These individuals are trained, tested, and prepared through the use of rigorous physical, mental, and emotional conditioning. They are placed in challenging situations, and their performance is examined critically under simulated, but realistic training conditions.

As behavioral science yields new information about how to train individuals to perform under high-stress work conditions, the U.S. military is eager to incorporate these lessons into its training protocols. There is a fairly robust literature already in place to show that well-learned tasks are most resistant to negative effects of stress. There is also a growing body of research whose purpose is to develop and optimize training conditions for jobs that require resilience to stress. Although training under pressure may be helpful to prevent “choking” or panic during subsequent performance under pressure, high levels of stress may also tend to degrade knowledge acquisition during training (Keinan & Friedland, 1984; Lee, 1961). As noted earlier in this chapter, Thompson et al. (2001) found that learning under the stressful conditions of skydiving had a significantly deleterious effect on subsequent cognitive task (recall) performance. Research in this area supports the need for a balanced emphasis on learning (knowledge acquisition and retention) and real-world preparation. At present, the most effective approach is delivered as *phased training,* which provides for initial knowledge acquisition under minimally stressful conditions. During a subsequent intermediate stage of phased training, trainees are familiarized with relevant criterion stressors and thus begin to develop more realistic expectations about field conditions. Finally, trainees are exposed to realistic stressors and practice their newly learned skills in conditions that successively approximate a true performance environment (Keinan, Friedland, & Sarig-Naor, 1990).

Virtual environments (VEs) are an appealing alternative to live training exercises because they provide a more safe and cost-effective context in which to learn and practice operational skills. It would be beneficial to determine how phased training toward cognitive resilience might be achieved in a low-cost VE. Virtual environments offer distinct advantages, such as the opportunity to manipulate task performance requirements and environmental demands, and thus expose trainees to a broader repertoire of experiences and a full variety of positive and negative effects of stress on attention, memory, and judgment and decision making. It is reasonable to expect that multiple practice opportunities in a VE would support the development of expertise, advance task training and performance from controlled to automatic processing, increase the bandwidth of attentional resources and executive function, reduce demands on memory resources required for task performance (Atkinson & Shiffrin, 1968; Shiffrin & Schneider, 1977), and enable rapid recognition-primed decision making (Klein, 1989). Reduced demands on cognitive resources may, in turn, promote more efficient information processing and cognitive resilience to stress in real-life environments such as combat. These suggested training effects could be empirically tested in VE with more flexibility and at less expense than in traditional "live" training environments. Attention and fatigue management techniques should also be considered for their potential impact as training techniques to sustain or improve cognitive performance under stress. Currently, there is little empirical evidence concerning the degree of transfer from VEs to real environments, but we anticipate that pertinent studies and assessments will be conducted and reported in the near future.

Contemporary theories of learning and instruction may provide generally helpful guidance, but are not adequate to identify specific conditions under which cognitive resilience might be promoted through training. In order to achieve a well-defined, integrated, and useful body of empirical evidence, researchers should consider and examine the effects of specific variables, factors, and conditions that may serve to moderate stress effects on cognition and thus advance our understanding of how best to promote cognitive resilience.

Selection, Assessment, and Measurement

The purpose of military selection and assessment is to identify individuals who are most likely to succeed in specific jobs. This effort is usually based on a series of target attributes that have been established as characteristic of candidates who succeed (select-in criteria) or not (select-out criteria) on the job. Most selection and assessment instruments include demographic, psychographic, and behavioral performance indicators.

There are a number of assessment instruments that claim to measure constructs related to cognitive resiliency (e.g., scales of hardiness, locus of control, optimism, and self-efficacy). Many of these tools have been used for the selection of special mission unit personnel and special duty positions within the military. Selection programs that implement screening procedures of this type typically compare results against previously identified profiles of successful operators. It is presumed that these characteristics are relevant to performance success and are thus desirable to replicate in prospective candidates.

Although psychometric instruments are often helpful to narrow the field of potential job candidates, it is not yet clear whether they effectively identify or predict resilience to stress per se. Unfortunately, as yet there is no direct method to assess cognitive resilience to stress, primarily because resilience itself is not yet sufficiently well-defined. Moreover, it seems that the more we learn about stress, the more we are forced to expand our understanding of resilience to accommodate potential direct and interactive influences of myriad individual differences and psychobiological system variables. This suggests the need for a fairly complex assessment instrument that is adequate to assess a variety of domain characteristics (e.g., emotion, personality, physiology) and moderating variables (e.g., outlook, disposition, training and/or experience).

The U.S. military and other organizations have devoted substantial efforts and resources to the research and development of high-fidelity training environments (VEs; Durlach, & Mavor, 1995; National Research Council, 1999) that can mimic real operational environments for the purpose of training. Recently, sponsors of VE development have suggested that VEs might also be useful to support selection and assessment (Schmorrow, Cohn, & Bolton, in press). The reasoning here is that if simulated environments are sufficiently realistic to promote learning, they can also be used to represent operational environments for selection based upon performance assessment.

Existing VEs already have the capability to record a wide variety of performance data and to apply assessment techniques. Currently available VE performance measures include body motion/gestures, eye movements, interaction with others (synthetic or real) in the environment, actions, arousal (via physiological measurement), and neurophysiologic measures. These and other indices could be applied to construct a multivariate assessment of cognitive resilience based on task performance in combination with other variable measures. For example, specific neurophysiologic signals associated with attention, memory, or JDM as recorded from individuals who perform well on cognitive tasks in stressful environments might provide an additional basis for job candidate assessment.

Certainly, more research is needed to define resilience operationally, to identify critical factors and markers of resilience, and to guide the design of scenarios to provide an informative context for the assessment of cognitive resilience. With respect to resilience assessment, it would likely be most efficient to begin with careful consideration of currently available and well-documented psychological and physiological measures. As noted previously, future research should also address known and putative moderators of stress effects on cognition as possible contributors to resilience.

Human Computer Interfaces and Operational Performance Support

The U.S. military uses state-of-the-art technology to support increased automation of the battlefield (FFW, 2004). For the purpose of the current chapter, we define operational performance support as any human performance intervention whose purpose is to improve operational task performance. Human factors engineering is an essential part of designing military operational systems and interfaces such that they will not exert a negative impact on performance. Human factors research and engineering can also be used to develop automated performance support systems. Computational decision-making models, cybernetic support systems, and augmented cognition are just a few of the information management systems that are under recent or current development as tools to reduce demands on operators' mental resources (attention and memory) and to facilitate more accurate and efficient information processing, judgment and decision making (Girolamo, 2005; Ververs, Whitlow, Dorneich, Mathon, & Sampson, 2005). Augmented cognition is an emerging field that seeks to extend operators' abilities, and ultimately their performance, using computational technologies. These technologies are explicitly designed to address bottlenecks, limitations, and biases in cognition, and to improve decision-making capabilities (D.D. Schmorrow, personal communication, July 25, 2005). For example, the demonstrated benefits of individual performance improvement via augmented cognition technologies (Schmorrow, 2005; Schmorrow, Kruse, Reeves, & Bolton, submitted) have the potential to generalize to distributed team decision making. Through the use of computer-aided situational updating the goal would be to reduce the time and cognitive effort required of the team to make decisions about emerging problems or threats. It is thus likely that augmented cognition may be an effective means to reduce task load and workload-related stress (Schmorrow, 2005; Schmorrow, Kruse, Reeves, & Bolton, submitted), and to encourage more positive cognitive appraisal. The net effect of these benefits might improve cognitive resilience in operational environments.

To the extent that automated systems could help to reduce negative effects of stress on cognition, they offer a promising new basis for cognitive resilience research and development. Tools and techniques that augment the capabilities of individual soldiers, team leaders, and commanders provide the greatest opportunity to improve performance in the battle space. For example, augmenting technologies could be used to assess individual physiological stress state and adjust information inputs accordingly to optimize decision making. Similar types of automated information systems could be implemented in a variety of other professional contexts such as law enforcement, fire fighting, and emergency services.

Conclusions and Recommendations

Resilience is a term generally used to refer to the ability to overcome stress and maintain an effective level of appropriate behavior or performance when confronted by obstacles, setbacks, distractions, hostile conditions or aversive stimuli. In this chapter, we have focused specifically on the possible effects of such external stressors on attention, memory, and judgment and decision making. To the extent that resilience can be learned, supported, or facilitated, strategies to improve cognitive resilience may offer potentially significant benefits for well-being and performance in a wide range of operational environments.

Observable effects of stress on attention, memory, and JDM are essentially alike. At low levels, stress facilitates cognitive task performance (e.g., recall, decision making). As stress increases, cognitive performance reaches an optimal level and additional resources can be mobilized in an effort to sustain optimal performance. Finally, excess stress causes performance degradation.

This is a well-established and generally reliable pattern of effect. However, actual human performance under stress may vary depending on any number of individual differences, moderating or protective factors, training or experience. Additional research is needed to develop interventions and strategies to sustain effective performance under positive stress states (facilitative stress, optimum stress, mobilization) and to improve performance by promoting resilience to negative effects of stress (degradation, “choking,” panic).

The objective of this chapter has been to review the essential effects of stress on cognition and to emphasize the need for additional research to determine how cognitive performance might be sustained or improved to overcome negative effects of stressors encountered in ordinary and extraordinary operational environments. The potential benefits of resilience research and development extend well beyond the military to include other high-performance occupations in aviation, public safety, law enforcement, and emergency services. Specific areas of applied concern that should be targeted include selection, assessment, measurement, training, and operational support.

There are several areas of cognitive resilience research that remain lacking. The first, and perhaps most unsettling, is the fact that there is little if any consensus concerning what cognitive resilience is and is not. Many related construct terms are used interchangeably, and resilience is poorly understood even among those most interested in its potential utility. We believe this volume provides an initial binding of the concept of resilience to encourage and facilitate more focused research in the future.

Certainly, much more can be learned about the role of cognitive resilience in the areas of personnel selection, training, and operational support. Thus far, efforts to select out non-resilient populations and to identify individuals least likely to succeed in various cognitively demanding tasks or critical professional roles have been relatively successful. However, we are as yet quite limited in our ability to select in resilient individuals and/or those who might be trained to sustain effective cognitive performance under stress. The U.S. military and related operational organizations have always been dedicated to the development of effective training strategies and procedures. It is essential to test and evaluate systematically the effectiveness of military training to ensure its greatest possible benefit in preparing service members for a wide range of real-world operational duties, including combat. Additional improvement can be encouraged by emphasizing the need for ecological validity, computer-aided fidelity, and the continued development of more realistically graduated or phased training models.

As a practical matter, it is important to meet the needs of military operators where they stand -- on the battlefield, in aircraft, and on ships. We need to make careful study of current operational support systems in order to improve the ways in which we augment operators' capabilities in specific operational environments. Specifically, we recommend investment in robust systems that are designed to accommodate and adapt to highly complex, dynamic environments. Likewise, there is a pressing need for targeted support of research in cognitive resilience as a subject matter that offers potential direct benefit to a broad variety of applied bio-behavioral and technological concerns, including the need for improved operational effectiveness under stress and the continued development of state-of-the-art cognitive systems.

Finally, it is important to recognize that human cognitive capacities may be strained by the complexity of modern technological and operational systems in many sophisticated occupational environments. The successful use of technology depends ultimately on the extent to which human operators find it useable. Understanding that cognitive performance may otherwise suffer under stress, it is important to encourage system and human-machine interface designs which support efficient task prioritization, tools to enable task simplification, and options to support information and resource management.

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Caption

Figure 1. The Yerkes-Dodson inverted “U” function and its relationship to identifiable states of stress states: facilitation, optimization, mobilization, degradation, “choking,” and panic.

Table 1. Possible applications for known moderators of cognitive resilience.

Moderators of Cognitive Resilience	**Possible Applications**
Cognitive Appraisal	Selection for low state- and trait- anxiety Training for effective resource allocation Interventions to reduce anxiety Operational support systems to optimize resources
Disposition and Coping	Selection for predisposition to optimism Training to increase self-efficacy and perception of control
Predictability and Control	Training to cope with uncertainty Operational support systems to facilitate/ improve predictive analyses
Experience and Expertise	Selection for experience and expertise Training to increase experience and expertise
The Presence of Others	Training to overcome impairment by exposure Operational support systems to reduce task complexity

Extreme Stress States	Training under extreme stress states to improve skill Interventions to prevent/treat panic Operational support systems to intervene and maintain operations until “choking” is overcome

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Phased training should not be confused with graduated stress training, which exposes trainees to increasing levels of stress over time. Graduated stress training programs have been shown to yield inferior outcomes (Friedland & Keinan, 1992).

Typically, the final phase of military training involves live fire exercises. Because live fire exercises are costly and can cause environmental and safety problems, exposure is generally limited. Thus, the final phase of basic military training may not fully prepare service members to achieve a high level of cognitive resilience to stress prior to deployment.