RESEARCH ARTICLE

Ready or Not: Enhancing Operational Effectiveness Through Use of Readiness Measures

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Current and future military operations require personnel to perform a multitude of mission tasks. Military personnel are required to execute these tasks, and to perform to high levels of expectation. Many of these tasks are complex and demand substantial cognitive readiness, which may optimize and enhance cognitive performance. Technologies are being developed to aid individual soldiers to successfully complete their missions; however, the proliferation of new technologies, coupled with the varying operational missions, make leveraging cognitive readiness a mandate for the achievement of military effectiveness and enhanced overall performance. It is important to have a militarily relevant psychological battery that can be used to assess each individual's cognitive capabilities and appraisals, factors that enhance military operational effectiveness. Assessing individual cognitive readiness becomes particularly important when researchers broaden their examinations of military effectiveness to assess team cognition, team behavior, and team effectiveness. We discuss the theoretical development and the components of the U.S. Army Research Laboratory's Readiness Assessment and Monitoring System (RAMS). Data from several studies are presented to illustrate the behavioral profiles of individuals in extreme operational environments. Data show how specific factors (e.g., personality, coping) contribute to performance in operational settings (e.g., command and control, chemical decontamination operations). Understanding the effect of cognitive readiness on overall military effectiveness not only has implications for selection, training, and system design, but also provides the basis for the proactive development and sustainment of optimal performance, both in individual soldiers, and in small teams or military units.

Keywords: assessment, cognition, cognitive readiness, performance, stress, decision making, salivary amylase, personality.

THIS WORK DESCRIBES an empirical and conceptual rationale for establishing a framework for evaluating the effects of perceived stress on human-system performance. It has culminated with the establishment of our laboratory's suite of readiness measures that may be used to predict and assess operational performance. The range of measures included within this battery, methods of selection, and supporting research to validate them are described.

A comprehensive assessment of the literature guided the selection of measures for inclusion in the Readiness Assessment and Monitoring System (RAMS). Our standardized paradigm comes after examining and challenging early theories relating stress to performance, such as the inverted-U description of performance posited by Yerkes and Dodson (58), and theoretical principles proposed initially by Selye (51). In this paper we address the research and subsequent validation of frameworks developed by Lazarus and Folkman (40) and Hancock (e.g., 28, 29), as they each contributed to the development of our readiness assessment paradigm.

Our work involves two intersecting areas: cognitive readiness and performance under stress. Cognitive readiness is the optimization and enhancement of human cognitive performance. It is a critical element for effective operational performance, especially for an individual's capability to perform multiple functions and to adapt to diverse and rapidly shifting threats. It is assumed that soldiers are always in some state of readiness due to their training to perform military occupational specialty-specific tasks. However, after initial training, time passes before the tasks are carried out in the field. A soldier needs to be ready to perform these tasks and must be able to pull on all the available knowledge and developed skills to apply them to a myriad of tasks as they arise. When military training and experience can be brought to bear on performance, even under conditions of stress, one can be said to have achieved a heightened state of readiness. Cognitive readiness is not exclusive to military applications; it can be applied to any domain that requires the active retrieval of skills and knowledge to perform a task.

An individual's susceptibility to stress and his or her ability to adapt is an integral component of cognitive readiness. Predictions and assessments of responses to stressful events require consideration of not only the kind and intensity of stress and the time of measurement, but also personal factors that account for individual variability in stress response. Due to this variability, a one-size-fits-all approach to measurement of readiness can be avoided through application of a standard methodology using a customized battery of measures.

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Behavioral researchers at the U.S. Army Research Laboratory (ARL) developed a cognitive readiness assessment battery with standardized procedures that provide the capability for multidimensional performance assessment and prediction (17,20). Linda Fatkin and Gerald Hudgens were integral in the initial development of the RAMS, and as it evolved, other scientists contributed to the inclusion of specific components and the application and validation of the RAMS. The established methodology is appropriate for assessing preparedness levels associated with complex cognitive tasks. This work describes the components of ARL's RAMS, and how specific factors contribute to performance in operational settings (e.g., command and control, military operations in urban terrain, chemical decontamination operations, etc.).

Historical Perspective of the RAMS Development

RAMS Development

The human factors community is routinely called on for information regarding capabilities of personnel to perform various tasks under stressful conditions approximating combat stress. Two decades ago, we received an initial assignment to provide estimates of performance decrements that might be expected for weapon systems whose human operators were performing under conditions of severe stress. These estimates were needed for models created to evaluate effectiveness of various weapon systems in combat operations scenarios. To address the limitations related to the existing methods of data collection under well-controlled, non-stressful laboratory conditions, first we needed to acknowledge challenges to collecting data under high-stress conditions, such as the degree of realism achievable in laboratory simulations and field studies, and the lack of precise understanding about the nature of "combat stress."

Our response was to develop a set of experimental procedures which met the following conditions: 1) that we elicit in the participants a stress response that can be identified as response to severe stress; 2) that we not subject participants to conditions exceeding minimal risk; and 3) that our research protocols be developed as a set of standardized procedures that can be applied with equal facility and validity to both laboratory and field test conditions. These standard procedures evolved into valid tests of human-system interaction for design evaluation purposes, valid field-derived data for researchers and their models, and as a usable framework for testing the effectiveness of various intervention techniques for enhancing cognitive readiness and improving performance under stress. This was accomplished through a long-term, multiple-phase program. In Phase I, we determined which "stress indices" were likely to reflect the effects of acute exposure to stress. After assessing a variety of physiological and psychological indices, we designed our program to elicit response profiles to a variety of stressors involving at least two distinct levels (i.e., high and low). We employed the same measures, standardized experimental procedures, and biological support labs and advanced analytical procedures for all biochemical assays across protocols. We used a consistent methodology to validate our approach and to develop a data set that could be used as a comparative metric in later research. In Phase II we conducted a series of laboratory and field studies in which a variety of psychosocial variables were manipulated to elicit stress responses from individuals. Lastly, in Phase III, we demonstrated how the procedures could be applied in field tests of major weapon systems and other developing and complex military technologies. Performance data were collected on individuals exposed to a wide range of conditions ranging from low to high stress.

Theoretical Framework

A theoretical framework guided our understanding of the interplay between individual characteristics, stress, and performance, and in identification of cognitive readiness measures. The first issue addressed was a definition of stress. Lazarus (39,40) conceptualized stress within the general context of homeostasis; a state of stress is produced when stressors (environmental or social) tax or exceed an individual's adaptive resources. Fatkin et al. (20) employed a conceptual definition of stress, similar to Lazarus' (40), where stress is "a multifaceted, dynamic, and interactive process with psychological and physiological dimensions." Our concept of stress emphasizes not only stressor variability (i.e., type, intensity), but also human variation in personality, perceptions, experience, and expectations. The defining characteristic of the stress experience is the interaction between individual appraisals and situational factors that contribute to human adaptation and performance.

The definition of stress and the relationship between stress and performance has been the subject of debates for decades (2,45). The Yerkes-Dodson Law (the "Inverted U hypothesis") has been used almost reflexively as an explanation for the effects of stress on performance. According to the Inverted-U hypothesis, there is a curvilinear relationship between arousal and performance. As arousal increases, performance increases, until an optimal level of arousal has been reached. Once this optimal level has been exceeded, performance begins to decline. Arousal, a measurable physiological component of stress, was the construct used for an explanatory mechanism of the effects of stress on performance (14,45). As an individual's level of arousal increased, his or her performance on a task should increase. The Inverted-U hypothesis had a "commonsense" appeal and was able to capture patterns of experimental findings, albeit post hoc, and as a result was applied as explanation for stress effects on performance (15,30,41).

Over time, the concept of unitary arousal fractured. Hancock and Ganey (30) reevaluated the application of the Inverted-U "law" to stress effects. According to Hancock and Ganey, this simplistic approach has significant shortcomings. Reevaluation of Yerkes and Dodson's (58) data with statistical methods not available in the early 20th century, showed that the data do not fit a strict U-shaped function. In a repeal of this "law," Hancock and Warm (31) developed the Extended-U theory that captures the central mechanisms of attention and adaptability as significant contributors to the effects of stress on performance. This Extended-U model served as the basis for the development of a comprehensive theory of stress and performance applied in the development of the RAMS (30,31).

Stress can be studied in multiple ways via calibration of the environment, assessing appraisal and coping mechanisms, and measuring a general physiological response (4,30,31). These are critical components of the total stress response and should not be examined in isolation. The impact of stress on performance is a three-part dynamic process: *input* → *adaptation* → *output* (30). Stress input can vary from extreme underload (hypostress) to extreme overload (hyperstress). Between the two extremes, a comfort region is located where adaptability is stable. Minor levels of stress may be absorbed by an adaptive capability and as a result there is no behavior change as a function of the output stress (30). As the stress levels increase (i.e., intensity, exposure time, and combination of both), the output stress will be affected as the adaptive capability is exceeded. The level of stress that can be tolerated without any effect on output is the "maximal adaptability" region. This evolution of stress and performance constructs has been a key theoretical springboard from which our approach to readiness assessment was developed. The RAMS was designed to capture the key features of the Extended-U theory, that is the environmental characteristics, individual characteristics (which may affect adaptability), and the individual's response to the stressor.

ARL's RAMS

General Description

The tools and methods selected for the ARL RAMS allow behavioral researchers to quantify the cognitive-perceptual influences of performance with analytical rigor. The RAMS includes a psychological stress assessment, a field practical, physiological measure of stress, and various cognitive performance assessment measures. The stress assessment identifies various components of stress (e.g., anxiety, depression) and is accomplished using self-report measures that correlate to plasma hormones.

The data captured by administering several of the RAMS instruments provide profiles of the type and intensity of the individuals' stress response across various operational settings, and identifies the trait and state factors contributing to those profiles. **Fig. 1-3** show response profiles for individuals engaging in various activities that ranged from low to high stress. This "diagnostic" information, descriptive about an individual's "readiness to perform," can aid assignment of countermeasures necessary for mitigating the stress response and enhancing operational performance.

Based on the research question, particular components of the RAMS are administered at specific times tailored to the nature of the study and experimental design. The wording of instructions to participants is crucial to ensure they report their perceptions regarding the situation of interest (e.g., instructions to participants must refer to the specific time period being evaluated). The screening and trait measurement instruments are generally given 1 or 2 d prior to the start of the experiment. The time to complete the selected components is between 30 and 90 min. The state measurement instruments are typically administered on a non-experimental day (Baseline), prior to a stress event (Pre-Stress), and then again immediately following critical events (During or Post-Stress). The time to complete the state assessments is between 2 and 5 min. When necessary, a post-test recovery metric is collected after the experiment or field test is completed (Recovery).

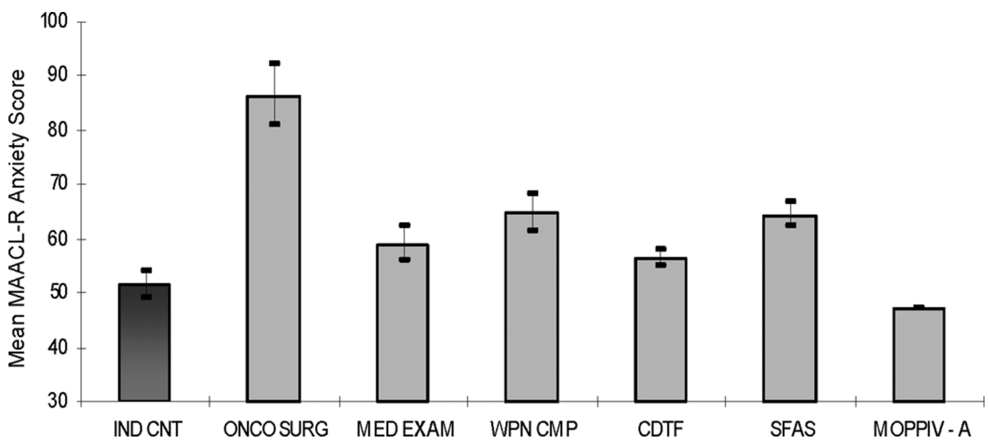

Fig. 1. Mean (± SEM) MAACL-R Anxiety scores for referent groups collected after specific events. The sub-scale Anxiety is a measure of anticipatory stress or a measure of the uncertainty component of stress. IND CNT: men investigated during normal work days when they were experiencing no unusual stress; ONCO SURG: men waiting in a hospital on a day when their wives were facing cancer surgery under general anesthesia; MED EXAM: medical students taking a written examination required for completion of the clerkship portion of their medical training; WPN CMP: soldiers representing elite units in marksmanship competition; CDTF: soldiers in mission-oriented protective posture (MOPP) IV participating in chemical decontamination training in a toxic agent environment; SFAS: participants in the Special Forces Assessment and Selection course at the JFK Special Warfare Center and School; and MOPP-IV: soldiers participating in a field study wearing MOPP-IV while traversing obstacles and natural terrain.

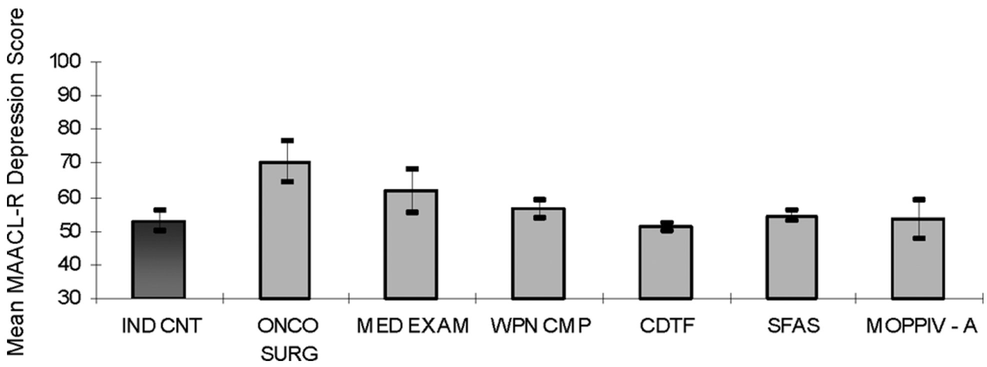

Fig. 2. Mean (± SEM) MAACL-R Depression scores for referent groups collected after specific events. The sub-scale depression is a measure of ones sense of self-failure or a sense of ceaseless striving and correlates with levels of morale and cohesion. Abbreviations as in Fig. 1.

Components of the RAMS

The battery of psychological questionnaires in the RAMS appear sensitive to stress that individuals experience across a wide range of military and civilian scenarios. The RAMS battery includes several standardized measures that demonstrate high construct validity and high test-retest reliability within the stress research literature.

Background screening information: Before each data collection, general background and demographic information along with reports of significant life events are obtained from participants to identify factors that may significantly influence or bias performance.

1. The General Information Questionnaire is a background questionnaire used to acquire demographic and general information (age, military occupational specialty, skill level, education, rank, Armed Services Vocational Aptitude Battery score) along with information regarding participants' overall physical fitness and health, current residential arrangements, and life experiences before military service, and motivation.

2. The Life Events Form (18,19) is used to identify and quantify the extraneous personal stressors that individuals may be experiencing at the time of the study, along with their available resources (e.g., family support) for dealing with stress.

Trait characteristics assessment battery: Trait measures are used to assess stable or inherent personality characteristics known to predict and/or correlate with performance. The four instruments in the battery are:

1. The Zuckerman-Kuhlman Personality Questionnaire, Form III (1,59) is used to measure five components of personality: Activity-Energy, Aggression-Hostility, Sociability, Neuroticism-Anxiety, and Impulsivity-Sensation Seeking. These components are derived from 99 true-false statements.

2. The Multiple Affect Adjective Check List-Revised (MAACL-R), Trait Form (42) has 132 adjectives and is used to measure five components of general affect: Anxiety, Depression, Hostility, Positive Affect, and Sensation Seeking. Instructions for the Trait Form direct individuals to check all adjectives to describe how they generally feel.

3. The Revised Ways of Coping CheckList identifies five individual coping efforts: problem-focused thoughts or behaviors, social support seeking, wishful thinking, blaming self, and avoidance (57).

4. The Uncertainty Measures are used to capture a participant's cognitive processes and respective coping styles used for decision-making. The Uncertainty Measures are new to the RAMS. They differ from the Revised Ways of Coping Checklist in that they assess coping with uncertainty rather than a general way of coping with daily life events.

A) The Need for Cognitive Structure (NCS) represents a continuum from the preference to use effortful, systematic evaluative processes such as hypothesis generation (low NCS), to the use of cognitive structuring, effortless category based processes such as schemas (high NCS) in order to make decisions and achieve certainty (5).

B) The Ability to Achieve Cognitive Structure

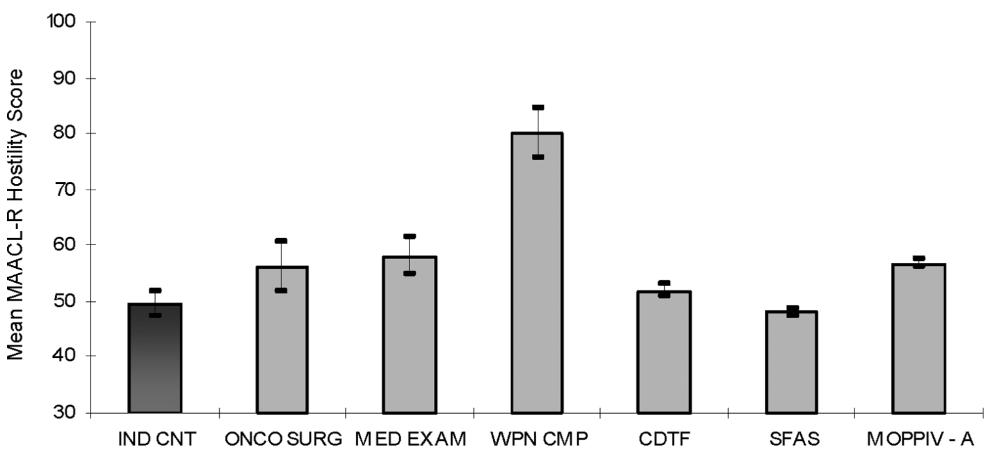

Fig. 3. Mean (± SEM) MAACL-R Hostility scores for referent groups collected after specific events. The sub-scale hostility is a measure of frustration, usually as a mismatch of the system and the human. Abbreviations as in Fig. 1.

(AACS) is the ability to apply the information processes consistent with an individual's level of NCS (5).

C) The Uncertainty Response Scale (URS) (27) assesses individual differences in coping with uncertainty on three levels: Emotional Uncertainty, Desire for Change (DC), and Cognitive Uncertainty (CU). Emotional Uncertainty is the degree to which an individual responds to uncertainty with maladaptive behaviors (e.g., anxiety and sadness). DC is the degree to which an individual enjoys novelty, uncertainty, and change. CU is the degree to which an individual prefers order, planning, and structure in an uncertain environment.

Psychological state characteristics assessment battery: State measures are used to assess the level of stress response to an event and identify the primary stress components that may correlate with performance. The five instruments in the battery are:

1. The MAACL-R State (42) uses the same 132 adjectives and measures the same five components described above. However, the instructions for the State form are to check all the words that describe how they "feel right now" or "during a particular time period."
2. The Situational Self-Efficacy provides an assessment of one's perceived ability to master new situations, or perform effectively (3,4). Self-efficacy is a composite of past success and failure experiences and influences the individuals' perception of how they might perform on tasks (52). Using this measure of task-specific efficacy, participants are asked to rate (from 1–10) their level of confidence in their ability to do well on the task(s) they are about to complete. Self-efficacy is associated with higher levels of motivation and performance for both civilian and military populations (18,33,49).
3. The Specific Rating of Events Scale (19) allows participants to rate (on a scale of 0–100) how much stress they experienced during a specific period of time on various events.
4. The Salivary Amylase Field Assay Kit was developed to be a quick and reliable method of obtaining on-the-spot physiological stress assessments in the field. Salivary α-amylase is a measure of activity of the sympathetic nervous system, is predictive of plasma catecholamine levels, and has been validated as a measure of stress and adaptability (10,11,35). Typically, amylase is collected just before, during, and immediately after a stressful event or specified set of tasks.
5. The Army Cognitive Readiness Assessment (ACRA) is a computer-based, performance testing system created by NTI, Inc.(Fairborn, OH) (47,48) that was developed as a resolution to the traditional barriers and concerns that persist in the field of cognitive performance testing, such as field practical measurement and the sensitivity of tests to operational environments. It gives researchers an automated tool for mapping complex cognitive functions to critical task demands by employing the "T-Matrix technique" of test selection. Once a researcher specifies the degree to which a given skill or cognitive attribute is required by a task, the T-Matrix technique employs an optimization operation, resulting in an ordered list of cognitive tests recommended for predicting performance of that task. The researcher selects the tests from the resultant list and specifies parameters for each test, which are then configured into an automated battery.

Psychological and Physiological Response Profiles

An integrated view of stress and performance should consider the task as the primary influence on cognitive stress (31). The observations of the task effects are one element of the dynamic model of stress. The psychological state components of the RAMS were used to develop a comparative metric for our research from which we evaluate the relative impact of a stressor on the experience of stress (i.e., psychological and physiological responses).

Psychological response profiles: One useful way of assessing the level and intensity of an individual's stress experience in a particular circumstance is to compare results from a single study (exposure to a stressful set of circumstances) with data from other studies that collected identical psychological and physiological measures. Comparisons from these "referent protocols" provide a method for estimating the relative stress experienced in a given situation and for studying the links between stress responses and performance in a variety of settings (24,35).

The data from the referent protocols in multiple lab and field experiments are used to quantify and understand the relative stress levels across various situational and operational tasks (e.g., 19,20,26). For example, Garrett et al. (26) evaluated the effects of two variants of a nuclear-biological-chemical (NBC) system on the mission task performance of dismounted soldiers. Participants completed the MAACL-R state prior to and while wearing several variants of mission-oriented protective posture (MOPP) IV*. Soldiers reported higher levels of depression (i.e., sense of failure to reach expected performance levels) while wearing the NBC configurations than when wearing their everyday battle dress uniform (BDU). Similarly, soldiers reported greater Hostility (i.e., frustration) during both NBC configurations than while wearing BDUs. These performance data were compared with that from soldiers in MOPP IV involved in chemical decontamination training and that from participants in the Special Forces Assessment and Selection course at the JFK Special Warfare Center and School. Anxiety levels were significantly lower than other encapsulation research efforts, which suggest that the soldiers in Garrett's study were confident in their ability to perform the duties required of them. Further, Hostility levels were higher and Positive Affect levels lower during encapsulation relative to the independent control, but were comparable to the other military scenarios.

These comparisons provide a method for quantitatively estimating the relative stress experienced in a

* MOPP IV is the U.S. military's highest level of chemical protectiveness, designating which level of personal protective clothing and equipment soldiers are to be wearing at a particular time on a contaminated battlefield.

given situation and for studying the links between stress responses and performance in a variety of settings, as well as a measure of practical significance regarding the effects of the stressor. It provides a perspective and insight about the relative magnitude of an effect and without the comparison we may attach too much importance to the absolute values of the stress experience without consideration of the context in which it occurs.

Relationship between salivary amylase levels and MAACL-R State Affect responses: The stress perception measures selected for inclusion in the battery correlate with a variety of physiological indices (11). We began our search with a wide variety of physiological parameters known to be useful as general stress indices, such as catecholamines, hormones, heart rate, and galvanic skin response (34). Chatterton et al. (11) investigated the production rates and concentrations of salivary α-amylase as a measure of adrenergic activity during conditions of physical and psychological stress in humans. Saliva and blood samples were simultaneously collected and they found significant associations between the concentration of salivary α-amylase and plasma levels of catecholamines, suggesting the same stimuli which increase concentrations of plasma catecholamines may activate sympathetic input into the salivary glands. Significant relationships between the psychological indices and salivary α-amylase lent evidence to the notion that we were measuring the same phenomenon and thus resulted in final selection of salivary α-amylase as a component of the RAMS (34).

While salivary α-amylase is a reliable physiological indicator of stress, it is important to determine which component of stress is contributing to the response. To assist with this diagnostic classification, the MAACL-R State is administered along with the collection of salivary amylase. For example, **Fig. 4** includes the results of the MAACL-R completed at times corresponding with the α-amylase collection. Two of the five subscales of the MAACL-R are illustrated to emphasize the difference in response profiles for the stress components. Scores from the Depression subscale were significantly and positively correlated with α-amylase levels, indicating that the soldiers' perceptions of failure to reach their initial performance expectations were a contributing factor to their stress levels. The low scores on the Anxiety subscale indicated that the physiological stress levels were apparently not attributable to anxiety or uncertainty of how to accomplish their tasks. From both a theoretical perspective and a human factors perspective, it is critical to consider all components of stress perception—those which show significant correlations (positive or negative) with salivary α-amylase as an overall indicator of stress levels, and those which indicate no correlation with the physiological metric. The absence of a significant correlation of α-amylase with anxiety is important for the identification of appropriate and effective countermeasures. Note, for example, that in military settings, additional training is typically called for as a panacea for enhancing performance. However, in our patient-litter decontamination example (Fig. 4), the low anxiety scores indicated that task uncertainty was not an issue for the participants. Therefore, specific task-related training would not be a suitable remedy in this situation. The identification of specific factors contributing to the stress response help point to potential solutions.

Psychological Correlates with Performance

Stress effects on performance are dynamic and are a function of the task (input) and characteristics of the individual, which influences his or her ability to cope with the task demands (adaptation) (28,29,31). For example, minor levels of stress can be absorbed by an individual's adaptive mechanism and will not affect

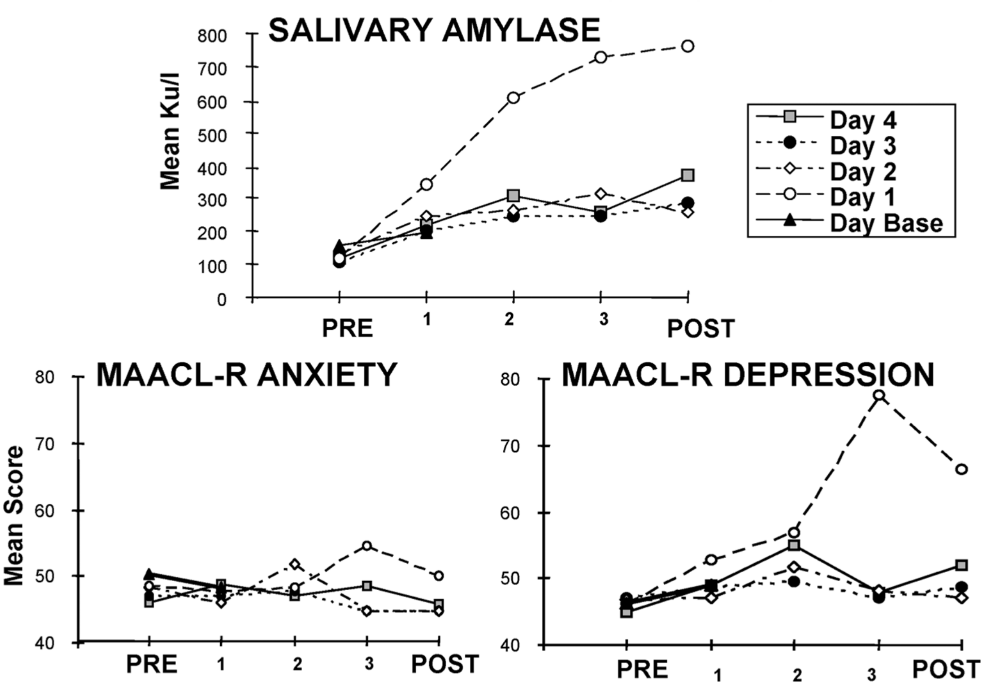

Fig. 4. Graph of salivary amylase levels and corresponding MAACL-R responses of soldiers performing patient litter decontamination tasks in mission-oriented protective posture IV (MOPP-IV) [adapted from Blewett et al. (10)].

functioning (e.g., behavioral change, output stress), but when the stress exceeds the capacity of an individual's adaptive mechanism, this will adversely affect functioning.

Individual differences in trait characteristics, such as personality, impact performance in various environments (37,44,50). The cognitive readiness measures in the RAMS identify characteristics (individual strengths and vulnerabilities) and quantify appraisals that affect cognitive performance (i.e., the output of the dynamic process). Cluster analyses are often performed to identify groups of individuals associated with different performance profiles (20,23,25). By minimizing the variance for each cluster across the measures, the cluster analysis groups individuals that have similar characteristics. The variables identified as the significant classification factors for a specific profile are subsequently included in regression equations used to develop performance prediction models. We have used these analytical procedures to address the effect of individual variability in personality characteristics and in reactions to situational and organizational factors within our investigations on marksmanship performance (20), cognitive performance within sustained operations (21), recruiter productivity (23), multitasking (8), and uncertainty (13), which are discussed below.

Marksmanship: Fatkin et al. (20) used cluster analyses to identify personality factors that contributed to marksmanship performance. Two distinct clusters of individuals emerged from the marksmanship data: one with a high stability profile (low MAACL-R Trait–Negative Affect and ZKPQ-III Neuroticism scores), and the other with a low stability profile (high MAACL-R Trait–Negative Affect and ZKPQ-III Neuroticism scores). Individuals with a low stability profile performed significantly better than those with a high stability profile.

Quantifying the levels of stress perceived by the individual and examining relationships with various tasks can broaden our understanding of how to influence skilled performance. In a study investigating the role of anxiety on the marksmanship performance of novices, Chung et al. (12) found that marksmanship aptitude accounted for 11% of the variance in shooting performance, and state anxiety explained an additional 34% above and beyond aptitude.

Sustained operations: Fatkin et al. (21) identified factors that contributed to cognitive performance during a 48-h sustained operations field exercise. Personality characteristics were significantly correlated with cognitive performance measured over the 2 d of sustained activity. Specifically, those individuals with high scores for Neuroticism-Anxiety performed worse on the logical reasoning and working memory tests than those with more stable scores. Similar results were reported by Mastin et al. (43), where they showed that sleep-deprived individuals with higher Neuroticism scores performed worse on a complex cognitive task than sleep-deprived individuals with lower Neuroticism scores.

Depending on the context, the Impulsivity-Sensation Seeking trait often correlates significantly and positively with cognitive performance (8,44). For example, during the second day of the sustained operations period, individuals who rated high on the Impulsivity-Sensation Seeking subscale of the ZKPQ-III performed better on short-term memory and logical reasoning tasks than those who rated low on the subscale (21).

Recruiter productivity: Fatkin et al. (23) used cluster analyses to identify trait factors that contributed to Army recruiter performance. Two subgroups with two distinct profiles on the MAACL-R trait emerged: a low dysphoria profile (i.e., low trait Anxiety, Depression, and Hostility) and a high dysphoria profile (i.e., high trait Anxiety, Depression, and Hostility). Recruiters in the low dysphoria group were significantly more successful than those in the high dysphoria group. The low dysphoria group accomplished 91% of their mission, while those experiencing higher levels of dysphoria accomplished only 69% of their recruitment goals.

Similarly, two subgroups emerged from the Life Event Form cluster analysis, a high-stress group and a low-stress group (23). Recruiters reporting low levels of life stress accomplished 105% of their mission, whereas recruiters reporting high levels of life stress accomplished only 75% of their mission. The decline in performance seemed to be related to individual vulnerabilities to the situational and organizational pressures. Countermeasures were implemented based on a list of recommendations and subsequently decreased the recruiters' pervasive stress and increased their productivity rates.

Multitasking: Branscome et al. (8) used cluster analyses to identify state factors that contributed to multitasking performance. Two subgroups emerged: a high self-efficacy group and a low self-efficacy group. The high self-efficacy group performed significantly better on a multitasking simulation (16) than the low self-efficacy group. There were also significant correlations between self-efficacy and the personality traits of Energy-Activity ($r = 0.236$) and Neuroticism-Anxiety ($r = -0.367$). Neuroticism-Anxiety and situational self-efficacy were significant predictors of performance. Those who reported high efficacy were less fearful, less sensitive to criticism, had high energy, and a preference for challenging work which may have contributed to their higher performance than the low self-efficacy group. Individuals are constantly assessing their range of capabilities, thus influencing subsequent behavior (3). If individuals perceive their capabilities as somewhat limited, they may minimize their effort, perform less effectively, or avoid relatively new situations.

Uncertainty: Individuals cope differently and make decisions differently in uncertain situations, which can affect performance under stress (9,13). Cosenzo et al. (13) and others (46,56) identified trait factors that influence coping with uncertainty. The three uncertainty metrics in the RAMS, the NCS scale (5), the AACS, and the URS (27) assess these factors. The NCS and AACS identify an individual's preferred and applied cognitive style (6,7). The interaction between preference and ability impact perceived stress and performance (see **Table I**). For example, individuals with a high NCS and high AACS prefer to use cognitive structuring (e.g., schemas) and have the cognitive ability to use that decision-making process, and as a result may experience less

TABLE I. CHARACTERISTICS OF THE COMBINATIONS OF NEED FOR COGNITIVE STRUCTURE (NCS) AND ABILITY TO ACHIEVE COGNITIVE STRUCTURE (AACS) LEVELS*

	NCS	
AACS	Low	High
Low	Low Piecemeal Processing	Low Cognitive Structuring
	Effortless Processing	Effortful Processing
	High Certainty	High Uncertainty
	Low Stress	Very High Stress
	Dysfunctional Impulsivity	Vigilance
High	High Piecemeal Processing	High Cognitive Structuring
	Effortful Processing	Effortless Processing
	Low Certainty	High Certainty
	High Stress	Low Stress
	Hypervigilance	Functional Impulsivity

Adapted from Bar-Tal, Kishon-Rabin and Tabak (6).

stress than individuals who may have a preference (i.e., NCS) but lack the ability to used their preferred cognitive style. Cosenzo and colleagues (13) showed that the level of NCS and AACS impacted on how long it took individuals to make decisions in a civilian Emergency Operations Center (high stress, high uncertainty, multitask environment). Individuals who preferred to use cognitive structuring (i.e., schema, scripts) completed calls faster than those with less of a preference.

In addition to cognitive style, individuals differentially employ coping mechanisms in high stress situations. The URS (27) assesses individual differences in coping with uncertainty. Cosenzo et al. (13) used the URS to assess coping mechanisms and showed that individuals with a high DC (high enjoyment for uncertainty, novelty, and change) and CU (individual's need to plan ahead, gather information, and seek clarification) completed calls faster than those with low scores on these subscales.

Results suggest that the responses on trait and state measures (i.e., personality, situational self-efficacy, and coping with uncertainty) can capture information about individual factors that may influence performance and can be used to direct modifications in training doctrine and equipment design.

Cognitive Correlates with Performance

In addition to stable trait characteristics and more fluid state characteristics, cognitive measures can provide insight into the effects of environmental stressors on performance. The newest addition to our suite of cognitive readiness measures is the ACRA, a computer-based, performance testing system designed to assess an individual's cognitive capabilities to complete mission-critical tasks (47,48). From these assessments, the ACRA is used to predict and quantify cognitive readiness.

The predictive and assessment capabilities of the ACRA system were first examined in a field study conducted as part of the U.S. Army's Future Force Warrior Advanced Technology Demonstration (22,55). Participants in a live-fire scenario performed a target identification task, an auditory task, haptic task, or combinations of these tasks. Using the "T-Matrix technique" for a selecting tests that probe task-specific demands, the ACRA-Live Fire battery included: 1) Dichotic Listening (divided attention); 2) Motion Inference (time estimation); 3) NovaScan C (multitasking, spatial manipulation, working memory); 4) Rapid Decision Making (reaction time, selective attention); and 5) Unstable Tracking (manual control). The ACRA-Live Fire battery and the psychological readiness measures were administered during training, baseline, pre/post-live fire, and after a 30-min recovery period.

Performance on the ACRA battery was significantly related to various performance metrics of the live fire exercise (22,55). Results showed significant bivariate correlations between the ACRA pre-live fire metric and

TABLE II. SIGNIFICANT CORRELATION RESULTS OF PRE-LIVE FIRE COGNITIVE READINESS METRICS AND LIVE FIRE PERFORMANCE.

	HAPTIC	HAPTIC MATH	HAPTIC MATH FIRE	MATH	MATH HAPTIC	FIRE HAPTIC
Dichotic Listening Total RT		0.584*				
Dichotic Listening Efficiency				0.813**		
Manikin Percent Correct (NovaScan)	0.678*	0.641*	0.688*			
Manikin Percent Correct Switch Required	0.699*	0.623*	0.679*			
Motion Inference Semantic Task Ave. RT Correct Responses				−0.848**		−0.579*
Continuous Memory Percent Correct				0.793*		
Continuous Memory (NovaScan) Percent Correct Switch Required				0.738*		
Multitask (NovaScan) Percent Correct No Switch Required Continuous Memory, and Manikin						0.663*
Manikin (NovaScan) Switch Cost No Working Memory					0.911**	
Rapid Decision Making RT Variance Correct Responses				−0.849**		−0.613*

*$p<0.05$
**$p<0.01$

the live fire performance, indicating the ACRA's potential as a metric of cognitive readiness. **Table II** includes the individual ACRA metrics that were significantly related to the live fire metrics, sharing similar cognitive demands. For example, Dichotic Listening Efficiency was significantly and positively correlated with percent correct on the "math alone" condition ($r = 0.813$, $p = 0.008$); both of these tasks require auditory perception. Percent correct on the "math alone" condition was also found to be significantly and positively correlated to percent correct on Continuous Memory both on the entire test ($r = 0.793$, $p = 0.019$) and when a switch was required ($r = 0.738$, $p = 0.037$). The Continuous Memory test, which presents math problems, requires not only processing numbers, but presents the soldiers with double-digit addition problems requiring some amount of working memory. Percent correct on the "math alone" condition was found to be significantly and negatively correlated to reaction time for correct responses for the Rapid Decision Making test ($r = -0.849$, $p = 0.004$) and the average reaction time for the semantic task of the Motion Inference Test ($r = -0.848$, $p = 0.004$).

The T-Matrix technique shows promise in its ability to produce a list of performance-based tests that directly relate to the demands of a task. Furthermore, this method produced a test battery that is sensitive to the effects of task load. Performance on the ACRA metrics from the pre- to post-live fire sessions and from post- to recovery sessions were affected by task load. The ACRA system is currently being applied and validated within other settings (e.g., tactical operations center environment, sustained operations scenario).

Applications of Readiness Measures

The cognitive measures can be used to quantify and predict cognitive readiness, whether it is a function of coping with stress or cognitive functioning. The measures have implications for system design and training for overall performance enhancement on an individual and team level. Researchers can use the readiness measures to guide the design of individual equipment, such as MOPP IV, and military systems such as decision aids and command and control displays. For example, if researchers wanted to evaluate the ease of use of one display type vs. another, they could administer the MAACL-R and examine the differences in psychological response profiles reported for use with the two displays. When administered in combination with other metrics, a broader perspective on the system (i.e., effectiveness and ease of use) could be garnered.

Another use of the readiness measures is to facilitate effective teaming. Trait measures of the RAMS are being used to identify the impact of individual characteristics within a multicultural team performing command and control functions. The goal of this effort is to develop a conceptual model of cultural adaptability for military operations and to develop products to improve leader and team adaptability in multicultural environments. The impact of factors from the uncertainty and personality metrics are important for understanding cultural diversity in cognition, particularly in military environments where tasks are accomplished through multicultural teamwork (54). Consideration of cognitive style differences may also be useful in determining how and what type of information to present in a display or training tool. Presenting information in a way that matches an individual's cognitive preference may enhance effectiveness and overall mission performance.

Summary and Implications

Current and future military cognitive challenges include high workload, management of sensors, time pressures, multi-tasking, and complex decision making. Research and applications of optimal performance principles and practices has included industrial, academic, and military environments. A common goal has been to assist individuals in achieving at optimal levels of performance and to do so consistently (32,38). In discussing peak performance, Jackson and Csikszentmihalyi (36) describe flow as an intrinsically rewarding experience that occurs when individuals perceive a balance between situational challenges and their abilities to meet related demands. While peak performance is considered a snapshot of superior performance, an optimal state of physical and cognitive readiness can be maintained for longer durations. Additional dimensions of cognitive readiness include the individual's state of awareness, clearly defined goals, motivated intentions, and a sense of focused action orientation.

Our research in the area of cognitive readiness represents the importance of individual differences in adaptation styles among personnel performing in diverse or rapidly changing environments. The more we learn about the individual factors affecting performance, the more likely we are to identify ways to achieve optimal performance. Maintaining optimal performance is critical within hostile, threatening, or uncertain circumstances. If the approach is to augment performance, then we need to identify the cognitive-behavioral actions that regulate an individual's stress states. The application of these measures should not be limited to countermeasures alone. We encourage an approach where individual factors are considered to augment the enhancement of operational performance.

Future considerations include a closer look at what individual factors might influence team interactions, possible mediating factors, and their effects over time. Each member of a team brings their own characteristics, levels of stress, and adaptation strategies to a situation. Research needs to examine how team dynamics are affected by combinations of team members' attributes. Effective interaction between individual capabilities, team interactions, and system functions will enable improved situational understanding, unsurpassed mobility, quick responses, and sustainability within continuous operations.

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