NAVAL HEALTH RESEARCH CENTER

CORTISOL SECRETION UNDER STRESS: TEST OF A STRESS REACTIVITY MODEL IN YOUNG ADULT MALES

R. R. Vickers, Jr.
L. H. Hervig
M. Poth
A. C. Hackney

Report No. 95-17

NAVAL HEALTH RESEARCH CENTER
P. O. BOX 85122
SAN DIEGO, CALIFORNIA 92186 – 5122

NAVAL MEDICAL RESEARCH AND DEVELOPMENT COMMAND
BETHESDA, MARYLAND

Cortisol Secretion Under Stress:
Test of a Stress Reactivity Model in Young Adult Males

Ross R. Vickers, Jr.[1]
Linda K. Hervig[1]
Merrilee Poth[2]
Anthony C. Hackney[3]

[1]Cognitive Performance and Psychophysiology Department
Naval Health Research Center
P.O. Box 85122
San Diego, CA 92186-5122

[2]United School of the Uniformed Health Sciences
Jones Bridge Road
Bethesda, MD 20814

and

[3]Applied Physiology Laboratory
Department of Physical Education, Exercise, and Sport Science
University of North Carolina
Chapel Hill, NC 27599

Report 95-17, supported by the Office of Naval Research, Department of the Navy, under work unit ONR Reimbursable 6252. The views expressed in this article are those of the authors and do not reflect the official policy or the position of the Department of the Navy, Department of Defense, or the U.S. Government. Approved for public release; distribution unlimited.

SUMMARY

Problem

Stress is commonplace in military training and operations. Understanding individual differences in sensitivity to stress could help in developing training and assignment procedures to optimize unit effectiveness under these conditions. However, models of biological stress sensitivity developed in other settings have not yet been tested in military populations.

Objective

This study tested a stress reactivity typology consisting of three types (reactive, neutral, and resistant) as a predictor of cortisol responses in recruits during military basic training.

Approach

Two samples of male U.S. Navy recruit volunteers (n = 40 and n = 53) completed a standardized personality questionnaire and provided blood samples at the beginning of basic training, near the middle of basic training, and at the end of basic training. Cortisol levels were determined for each blood sample. Personality measures describing the respondent on five major personality dimensions (neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness) were used to classify recruits as stress reactive, stress neutral, or stress resistant. The individual dimensions and typological status were compared as predictors of cortisol in correlational analyses, including structural equation modeling.

Results

Cortisol was highest early in training as would be expected based on past research indicating higher stress at this time. Cortisol measured at different points in training was reliably related to personality, but only after controlling for stable individual differences in cortisol. In typological analyses, stress reactive individuals showed higher cortisol at the end of basic training. In dimensional analyses, agreeableness was related to higher cortisol in the middle of training, and conscientiousness was related to lower cortisol at the end of training.

Conclusion

The dimensional approach to personality was preferable to the typological approach because it predicted cortisol secretion in a wider range of settings. However, stress reactivity research provides independent evidence that personality predicts cortisol primarily under low to moderate stress conditions, as observed here. Those independent observations provide corroboration of the unexpected finding that personality predicted cortisol under low stress conditions rather than high stress conditions. Cortisol can be predicted based on personality if the situation can be specified sufficiently to establish, first, that stress levels are low enough to be below a threshold level for generalized activation of the cortisol response and, second, which personality attributes are relevant to the challenges provided by the environment at the time of observation.

Introduction

The influence of psychological attributes on responses to stress has been extensively studied, but reliable associations between personality measures and biological stress indicators have been more difficult to identify than might be expected. One reason for this difficulty may be that psychobiological stress research typically has employed dimensional measures of personality. Such measures assume that personality differences are properly conceptualized as differences in the degree or quantity of a personality attribute. The present investigation contrasted the predictions obtained from this dimensional approach with the predictions obtained from a stress reactivity typology to evaluate the possibility that differences in kind, rather than differences in quantity (Meehl, 1992), are the key to understanding stress responses.

Personality and Cortisol

New approaches to understanding the influence of personality on cortisol responses to stress are needed because past efforts have been rather unproductive (Dabbs & Hopper, 1990). The published literature indicates a weak association between neuroticism and cortisol secretion. In 14 studies that included a measure of neuroticism or the anxiety and/or depression facets of this general domain, six studies (Bloch & Brackenridge, 1972; Bohnen, Nicolson, Sulon, & Jolles, 1991; Brier et al., 1987; Chodzko-Zajko & O'Connor, 1986; Dabbs & Hopper, 1990; Vickers, Hervig, Wallick, Poland, & Rubin, 1987) have produced small to moderate positive correlations (i.e., $.10 < r < .40$). Three studies have produced positive values near zero (Brandtstater, Baltes-Gootz, Kirschbaum, & Hellhammer, 1991; Hytten, Jensen, & Vaernes, 1989; Rahe, Karson, Howard, Rubin, & Poland, 1990). The remaining five studies have produced negative correlations (Ballenger et al., 1983; Kagan, Reznick, Snidman, Gibbons, & Johnson, 1988; Moss, Yao, & Panzak, 1990; Salmon et al., 1989; Tennes & Kreye, 1985). The overall distribution of correlations in these 13 studies tends weakly toward positive correlations, particularly if attention is restricted to studies of adults, since two of four negative correlations involved children (Kagan et al., 1988; Tennes & Kreye, 1985).

The weak evidence for personality-cortisol relationships does not appear to be a result of focusing on the wrong personality dimension. Evidence relating cortisol to other personality dimensions is less extensive than that for neuroticism, but the available results generally are negative. Several studies using standardized inventories providing reasonable coverage of the five-factor personality domain (Digman, 1990; John, 1990) have shown that neuroticism is the primary personality correlate of cortisol (Chodzko-Zajko & O'Connor, 1986; Dabbs & Hopper, 1990; Rahe et al., 1990). Thus, neuroticism may be the most potent predictor of cortisol in the general personality domain even though it is a weak predictor.

Stress Reactivity Typology

The general failure to identify dimensional correlates of cortisol secretion contrasts with evidence that cortisol secretion under stress is reliably related to ratings of psychological defenses that are stable across time (cf., Vickers, 1988). The fact that cortisol secretion is reliably related to some psychological measures makes it reasonable to consider limitations of prior personality research as the basis for the largely negative findings to date. Meehl's (1992) recent observations regarding the potential value of typological measures is relevant in this context because research in children and nonhuman primates points to a typological alternative to the standard dimensional approach. The relevant typological model has been labeled "stress reactivity" by researchers studying nonhuman primates (Higley & Suomi, 1989; Sapolsky, 1990a,b).

The prototypical stress reactive type is identified by a pattern of overlapping behavioral and endocrine reactions to psychosocial challenges (Higley & Suomi, 1989). Stress reactive behaviors include being " . . . less likely to approach new stimuli, more anxious, more socially inhibited, and less likely to attempt challenging situations" (Higley & Suomi, 1989). Stress reactive animals also are more acquiescent and show depressive symptomatology (Higley & Suomi, 1989). A complementary behavior pattern for stress resistant animals includes the ability to discriminate between threatening and nonthreatening situations and using aggression only when it is likely to be successful (Sapolsky, 1990a,b).

Nonhuman primate studies of stress reactivity indicate that cortisol secretion patterns in reactive animals differ from those in nonreactive animals in two respects. Reactive animals have higher basal values of cortisol than do resistant animals, and reactive animals react more strongly to acute situational stresses (Higley & Suomi, 1989; Sapolsky, 1990a,b).

While the empirical roots of the stress reactivity typology lie in observations of nonhuman primates, the model appears relevant to humans. A similar pattern of behaviors has been identified in inhibited children (Kagan, 1989; Kagan, Snidman & Arcus, 1992). Here again, the pattern may be relevant to cortisol secretion because a weak trend toward higher cortisol has been reported in inhibited children (Kagan et al., 1988).

The present study tested the hypothesis that a stress reactivity typology would predict cortisol secretion in young adult human males using a typological classification developed by Vickers (1991). This classification combined behavioral observations of reactive and nonreactive types with the five-factor model of personality (Digman, 1990; John, 1990) to define hypothetical reactive and resistant personality profiles. Cluster analyses of NEO Personality Inventory (Costa & McCrae, 1985) scores were used to determine whether the hypothesized types were present in a population of male U.S. Navy recruits. The initial analysis produced five empirically reliable clusters, two of which approximated the hypothesized reactive and resistant profiles well enough to be acceptable as provisional measures of the typology. The stress reactive cluster (hereafter designated "R+" to indicate a stronger than average response to stress) combined high neuroticism with average openness, low conscientiousness, low extraversion, and low agreeableness. The stress resistant cluster (hereafter designated R- to indicate a weaker than average stress response) was the opposite of the R+ profile, except for a tendency to be above average, rather than just average, on openness.

Subsequent research has supported the construct validity of the clusters as representation of the hypothetical three-group stress reactivity classification. First, base rates for the R+ and R- types were 16.5% and 16.1%, respectively, in the initial study. These values were near the 15% rates for each type suggested by Kagan and his colleagues (Kagan, Reznick, & Snidman, 1986; Kagan, 1989), although these figures have recently been revised to as high as 20% for inhibited and 35% for uninhibited (Kagan et al., 1992). Second, the R+ and R- clusters were the only profiles that replicated in a second study utilizing a different personality inventory in a different military population (Vickers, Walton, Hervig, & Conway, 1993). Third, R+ individuals had a higher than average failure rate in military basic training, while R- individuals had a lower than average failure rate (Vickers, Hervig, & Bischoff, 1991; Vickers et al., 1993). The remaining three groups in the provisional typology had essentially average failure rates. Thus, the reactive and resistant clusters were replicable and were related to adaptation to a stressful situation. The other three groups were reliable in the development phase of the cluster analysis, but those groups did not replicate across populations and appeared to be equivalent with respect to adjustment to stress. The three intermediate clusters, therefore, were collapsed into a single group (hereafter designated "N" to indicate a neutral or average stress response).

Study Hypotheses. The central hypothesis of this study was that the stress reactivity typology would predict cortisol secretion better than a dimensional model of personality. The conceptual basis for this prediction was the assumption that no one personality characteristic operates in isolation to determine stress responses. Instead, personality attributes occur in meaningful combinations that influence the dynamics of reactions to situational stimuli in ways that can increase and prolong stress for some while truncating stress for others. The stress reactive personality profile is assumed to increase and/or prolong stress while the resistant pattern can truncate stress processes.

As an example of the possible processes underlying stress reactions in a given situation, consider a job performance setting. The low conscientiousness of the reactive individual will tend to be associated with poor performance (e.g., Barrick & Mount, 1991), thereby increasing the probability of getting a poor performance rating and missing out on organizational rewards. The emotionality of the R+ individual coupled with his/her tendency toward disagreeable behavior can produce anger and depression in response to this event. These reactions increase the probability of negative interpersonal interactions under stress and may lower motivation for present performance. In an extreme case, a passive-aggressive resistance to attempts to improve work may result. Options for coping with job difficulties are restricted because the person may find it difficult to obtain social support from coworkers or to engage in effective problem solving behaviors (McCrae & Costa, 1986; Vickers, Kolar, & Hervig, 1989). The only coping option may be to focus on emotional control, but this option will not resolve the problems and may further distract the individual from the requirements for effective performance.

This hypothetical translation of predispositions into situational dynamics is expected to yield low positive affect, high negative affect, and poor interpersonal interactions on the job. Actions based on this set of perceptions can be expected to produce a vicious circle on the job. Across time, the R+ pattern could lead to chronic stress and strong conditioned reactions to specific events that the average person would see as trivial. The end result may be higher chronic levels of biological stress markers coupled with a stronger reaction to acute stressors, possibly because of stronger emotional reactions to those stressors.

The key element of the hypothetical processes is that they depend heavily on the integrated pattern of personality attributes. The typological perspective emphasizes the potential for the individual personality elements of the R+ and R- profiles to reinforce one another to define coherent, internally consistent cognitive frames of reference and behavioral patterns. Differences in the integrated personality structures for reactive and resistant types are expected to lead to different patterns of interaction with the environment, thereby yielding qualitatively and quantitatively distinct patterns of psychological experience and behavior that might exacerbate stress. This characterization is consistent with treatments of types as differences in kind rather than quantity (Block, 1971; Meehl, 1992). The critical point for the present study is that the qualitative differences between R+ and R- types is expected to produce quantitative differences in cortisol secretion as one product of the typological differences in psychosocial processes.

Methods

Samples

Study hypotheses were tested in two samples of male U. S. Navy recruits who volunteered to participate in a study of the effects of stress on health in basic training after being given informed consent. The average volunteer in the first sample ($\underline{n}$ = 40) was 18.7 years ($\underline{SD}$ = 2.6; range = 17-27) years of age. Most volunteers (80%) were Caucasian; 8% were African-American; 5% were Hispanic; other minorities comprised the remaining 8% of the sample. Nearly all of the recruits had received a high school diploma (90%) or Graduate Equivalency Degree (3%).

The average volunteer in the second sample ($\underline{n}$ = 53) was 19.7 years ($\underline{SD}$ = 2.6, range = 17-30) years of age. Again, most volunteers (77%) were Caucasian; 9% were African-American; 9% were Hispanic; and 4% were Asian. Nearly all of the recruits had received a high school diploma (83%) or Graduate Equivalency Degree (13%).

Situation

Military basic training was an appropriate situation for studying cortisol reactions to stress. Basic training is stressful whether stress is defined as the presence of adaptive challenges (Bourne, 1967; Janis, 1945; Maskin & Altman, 1943; Zurcher, 1968), conditions that elicit emotional strain (Datel & Engle, 1966; Datel, Engle, & Barba, 1966; LaRocco, Ryman, &

Biersner, 1977), or conditions that elicit endocrine and immunological responses consistent with current stress concepts (Rose, Poe, & Mason, 1968; Vickers, Hervig, Levy, Whiteside, & Herberman, in preparation; Vickers, Hervig, Wallick, Poland, & Rubin, 1987). If stress reactivity influences responses to challenging, emotionally stimulating situations, basic training is a suitable setting for studying these influences.

Personality Measures

The 181-item NEO Personality Inventory (NEO-PI; Costa & McCrae, 1985) was administered to the participants with a 5-point Likert scale format with options ranging from "Strongly Disagree" through "Neither Agree nor Disagree" to "Strongly Agree." The inventory assesses five major domains of personality, including:

a. Neuroticism (N) assesses adjustment versus emotional instability. Specific facets of neuroticism include anxiety, hostility, depression, self-consciousness, impulsiveness, and vulnerability to stress.

b. Extraversion (E) assesses qualities of interpersonal interactions combined with typical activity levels, excitement seeking, and capacity for positive emotions. Specific facets include interpersonal warmth, gregariousness, assertiveness, typical activity level, excitement-seeking propensity, and frequency and intensity of positive emotions.

c. Openness to experience (O) assesses the person's tendency to seek and become deeply involved in new experiences and to try to fully appreciate and be aware of one's feelings and surroundings. Specific facets of openness include frequency of daydreaming and fantasy, value placed on aesthetics, sensitivity to one's feelings, preference for novel activities, intellectual curiosity, and tolerance of a range of ideas.

d. Agreeableness (A) assesses interpersonal orientation in terms of tolerance versus antagonism or trust versus cynicism.

e. Conscientiousness (C) assesses organized, persistent pursuit of goals in contrast to unreliability, sloppy work and undependability.

The definitions of A and C are based on the conceptualization of these constructs current in 1985. More detailed definitions of A and C that have been developed recently provide conceptual refinements (Costa & McCrae, 1992; Costa, McCrae, & Dye, 1991).

The five-factor dimensional measures were translated into stress reactivity typology classifications using linear classification functions developed by Vickers (1991). The linear classification functions were applied to the data from each individual, and the individual was assigned to the group for which his classification function score was highest. Two dichotomous variables were computed to serve as indicators of reactivity. One variable was scored "1" if the individual was reactive and "0" otherwise; the other variable was scored "1" if the individual was resistant and "0" otherwise. These dichotomous indicators, hereafter "reactive" and "resistant," respectively, were used in correlation and regression analyses for comparison to the results obtained in similar analyses with the five-factor dimensional model.

Blood Sampling

Blood samples were drawn three times during basic training using standard venipuncture procedures. The first blood sample was taken during a processing period 3 days after arrival at basic training and 2 days prior to starting the formal training schedule. The second blood sample was drawn 18 days after starting the formal training schedule. The third blood sample was taken 28 days later. The time of day at which blood samples were drawn was determined by the training schedule for each recruit's training company. In the first sample, blood drawing was begun at 0700, 1030, and 1000 for the three draws, respectively, except for one company which was not available for the first blood draw until 1230. In the second sample, initial blood draws were begun at 0530. The second blood draw began at 0900 for four companies, but at 0645 for one company. The third blood draw began between 0630 and 0715, depending on the arrival time of the company being studied.

Cortisol Assays

Cortisol values were determined by commercial radioimmunoassay kits produced by DPC, Inc., Los Angeles, CA. The assay involved a highly specific solid-phase single antibody methodology. The reported coefficient of variation for the procedure is between 3.0% and 10.1% over the range from 1 gm/dl to 50 gm/dl. This range covered all but two of the samples in the present study. The two extreme values were dropped from the analyses as outliers.

Cortisol Indicators

Examination of the raw score cortisol frequency distributions identified several extreme cortisol values in the raw data. Square root and logarithmic transformations of the raw data were examined as potential means of reducing the potential effects of these extreme data points on parameter and significance estimates. The analyses reported here used the natural logarithm of the raw values because this transformation approximated a normal distribution better than the square root transformation did.

Composite cortisol measures were constructed to assess chronic cortisol differences and stress responses because past research on stress reactivity suggests these elements of cortisol secretion differ between reactive and resistant animals. Chronic cortisol differences were represented by the average of the log-transformed data. This value corresponds to the geometric mean of the raw cortisol values. Stress responses were evaluated by the difference between the initial cortisol determination, taken at a time that is believed to be the most stressful in basic training (see Situation, p. 7), and the final cortisol determination, taken when the psychosocial situation has stabilized. Given the logarithmic transformation, this difference reflects the ratio of the raw cortisol for high stress to the raw cortisol value for low stress.

Analysis Procedures

Frequency distributions for the cortisol and personality measures, bivariate correlations between personality and cortisol, and multiple regression equations to predict cortisol from personality were obtained using the relevant procedures in the SPSS-X statistical package (SPSS, Inc., 1988). Additional analyses developed structural equation models with the LISREL VII program as described in the text (Joreskog & Sorbom, 1989).

Results

Cortisol Across Time

Descriptive statistics for the cortisol values in the two samples are provided in Table 1. A multivariate repeated measures analysis of variance with blood draw occasion as a within-person factor and sample as a between-persons factor indicated that cortisol levels changed significantly across time (multivariate $F_{2,90} = 21.75$, $p < .001$), but there was no difference between groups ($F_{1,91} = 1.92$, $p < .169$) and no group-by-time interaction (multivariate $F_{2,90} = 1.84$, $p < .165$).

The pattern of differences contributing to the significant variation across days was examined by follow-up t-tests for correlated measures with the two samples combined. Draw 1 cortisol was significantly higher than Draw 2 cortisol ($t = 6.82$, 92 df, $p < .001$) and Draw 3 cortisol ($t = 3.59$, 92 df, $p < .001$). Draw 2 cortisol was lower than Draw 3 cortisol ($t = -3.51$, 92 df, $p < .001$).

Table 1
Descriptive Statistics for Cortisol by Sample

	Mean	S.D.	Cross-Time Correlations		
Sample 1					
Draw 1	2.72	.47	1.000		
Draw 2	2.48	.42	.359	1.000	
Draw 3	2.54	.43	.339	.329	1.000
Sample 2					
Draw 1	2.81	.20	1.000		
Draw 2	2.46	.34	.235	1.000	
Draw 3	2.69	.23	.256	.254	1.000

NOTE: Sample 1, n = 40; Sample 2 n = 53.
Data presented for logarithmic transformation of cortisol.

Although the interaction of sample and time of blood draw was statistically nonsignificant in the analysis of variance, examination of the replicability of specific differences suggested that omnibus test for differences might have been misleading. Both of the comparisons between Draw 1 cortisol and later cortisol were significant in each sample ($t > 2.21$, $p < .033$ or better). However, the overall difference between the Draw 2 and Draw 3 cortisol values was confined largely to the second sample ($t = -4.66$, 52 df, $p < .001$) and was not significant in the first sample although the difference was in the same direction ($t = -0.75$, $p < .457$).

The correlations between cortisol measured at different times in training were noteworthy for their consistency over the full training period. In both samples, the correlation between the Draw 1 and Draw 3 cortisol values was virtually identical to the correlations between pairs of temporally adjacent blood draws. This correlation pattern is consistent with the existence of a highly stable source of individual differences variance in cortisol. Applying Heise's (1969) path analytic method for decomposing a pattern of correlations into stability and reliability components, stability from the first draw to the third was estimated at .973 for Sample 1 and 1.048 for Sample 2. The latter stability estimate exceeds the theoretical upper limit of 1.00, presumably because of sampling variability in the estimation of individual correlations.

The stable component of cortisol variance contributed modestly to overall variance. Applying Heise's (1969) methods, reliability estimates were .348 for Sample 1 and .233 for Sample 2. These reliability estimates reflect the proportion of variance in cortisol determinations that can be attributed to the stable individual differences in cortisol. The presence of substantial variance specific to each blood draw also was indicated by the fact that Cronbach's coefficient alpha when that statistic for the linear composite of the three values was modest in both samples (Sample 1, alpha = .608; Sample 2, alpha = .471).

Table 2
Personality Correlates of Cortisol Secretion

	Blood Draw: 1	Blood Draw: 2	Blood Draw: 3	Trait Cortisol	Stress Response
Five-Factor Model					
Neuroticism					
Sample 1	.10	.08	.37*	.24	-.21
Sample 2	.11	.03	-.13	.01	.20
Extraversion					
Sample 1	-.09	-.10	-.22	-.18	.11
Sample 2	-.14	-.13	-.24*	-.23	.10
Openness to Experience					
Sample 1	.14	-.02	-.11	.01	.22
Sample 2	-.16	-.04	.08	-.05	-.19
Conscientiousness					
Sample 1	-.10	-.11	-.50**	-.31*	.32*
Sample 2	.16	.33**	-.08	.23	.19
Agreeableness					
Sample 1	-.10	.21	-.13	-.01	.02
Sample 2	.01	.22	.14	.20	-.11
Stress Reactivity Model					
Reactive (R+)					
Sample 1	.02	.01	.25	.13	-.18
Sample 2	.01	-.23	.19	-.06	-.16
Resistant (R-)					
Sample 1	-.06	-.16	-.49**	-.31*	.35*
Sample 2	.07	.07	.04	.08	.02

* $p < .05$ ** $p < .01$

Note: Sample 1, n = 40; Sample 2, n = 50. Five-factor measures are the NEO-PI domain scales. Stress reactivity measures were dichotomies with "Reactive" scored "1" if the person was in the reactive group and "0" otherwise. "Resistant" was scored "1" if the person was in the resistant group and "0" otherwise. One-tailed significance tests were used for all determinations to provide a consistent significance criterion given directional hypotheses for neuroticism, reactive, and resistant.

Personality Correlates of Cortisol Measures

Bivariate correlations between personality and cortisol generally echoed the pattern of weak and/or inconsistent findings in previous research (Table 2). No correlation was significant in both samples, although there was some consistency in the relationships across samples. This consistency resulted in some indications of cumulatively significant associations when the method of adding ts (Rosenthal, 1978) was applied to the data. Considered from the perspective of the pooled results, significant associations between cortisol and personality were as follows:

a. **Draw 1 Cortisol:** No personality variable was a significant predictor.

b. **Draw 2 Cortisol:** Agreeableness predicted cortisol at the second blood draw (average $r = .22$, pooled $z = 2.01$, $p < .023$).

c. **Draw 3 Cortisol:** Significant predictors were Conscientiousness (average $r = -.28$, pooled $z = -2.80$, $p < .003$), resistant (average $r = -.21$, pooled $z = -2.20$, $p < .014$), reactive (average $r = .22$, pooled $z = 2.01$, $p < .023$) and extraversion (average $r = -.23$, pooled $z = -2.14$, $p < .017$).

d. **Average cortisol:** Extraversion was a significant predictor (average $r = -.21$, pooled $z = -1.89$, $p < .030$).

e. **Stress Response:** Conscientiousness (pooled $r = .25$, pooled $z = 2.36$, $p < .010$) and resistant (pooled $r = .17$, pooled $z = 1.69$, $p < .046$) were significant predictors. Reactive (pooled $r = -.17$, pooled $z = -1.55$, $p < .113$) approached significance.

All other pooled correlations were nonsignificant (absolute $r < .15$; absolute $z < 1.21$, $p > .114$).

Stress Effects on Personality-Cortisol Correlations

The temporal pattern of correlations was analyzed to address the issue of whether stress affects personality-cortisol relationships. If personality is related to cortisol under stress, but not under less challenging conditions, personality should be most strongly related to cortisol at the beginning of training.

Tests for temporal trends in the personality-cortisol associations began with analyses of covariance in which personality was a covariate, sample was a between-persons factor, and blood draw was a within-person factor. The focal point of these analyses was the test for parallelism of regression lines, because nonparallel regression lines for the covariate would indicate significant variation in the cortisol-personality associations across time.

Three significant personality-by-time interactions were identified. These interactions involved the reactive dichotomy (multivariate $F_{2,88} = 3.54$, $p < .033$), conscientiousness dimension (multivariate $F_{2,88} = 6.65$, $p < .002$) and agreeableness dimension (multivariate $F_{2,88} = 3.26$, $p < .043$). The resistant dichotomy produced a trend that approached significance (multivariate $F_{2,85}$ = , $p < .089$). All other personality measures produced clearly nonsignificant ($p > .615$) results. The reactive, resistant, conscientiousness, and agreeableness results replicated across samples since the three-way interaction of personality, time, and sample were nonsignificant for each personality measure ($p > .635$, .147, .474, and .502, respectively).

Pairwise comparisons of correlation coefficients using Steiger's (1980) equation 14 for evaluating the significance of differences between two elements of a correlation matrix provided follow-up analyses to identify the bases for the significant personality-by-time interactions. This equation was applied separately to the data from each sample, and the method of adding zs (Rosenthal, 1978) was applied to the resulting z-values to assess the replicability and combined significance of the trends considered across samples. These analyses indicated that:

a. The reactive dichotomy-cortisol correlation was more positive for Draw 3 than for either Draw 1 (Sample 1, $z = -1.64$; Sample 2, $z = -1.57$; pooled $z = -2.27$) or Draw 2 (Sample 1, $z = -1.74$; Sample 2, $z = -3.42$; pooled $z = -3.65$).

b. The conscientiousness-cortisol correlation was substantially more negative for Draw 3 than for either Draw 1(Sample 1, $z = 3.17$; Sample 2, $z = 3.00$; pooled $z = 4.36$) or Draw 2 (Sample 1, $z = 3.10$; Sample 2, $z = 3.47$; pooled $z = 4.64$).

c. The agreeableness-cortisol correlation was more positive at Draw 2 than at Draw 1 (Sample 1, $z = 2.16$; Sample 2, $z = 1.56$; pooled $z = 2.63$) or Draw 3 (Sample 1, $z = 2.42$; Sample 2, $z = .53$; pooled $z = 2.09$). Clearly, the second of these cumulatively significant trends was attributable largely to the difference in the first sample.

d. The resistant dichotomy-cortisol correlation was more negative at Draw 3 than at Draw 1 (Sample 1, $z = 3.32$; Sample 2, $z = 0.35$; pooled $z = 2.60$) or Draw 2 (Sample 1, $z = 2.70$; Sample 2, $z = 0.39$; pooled $z = 2.18$). In both instances, the difference was confined largely to the first sample.

Structural Equation Models

Structural equation models (SEMs) were developed to clarify the interpretation of two facts embodied in the patterns of association previously noted. First, personality was not related to the stable individual differences in cortisol. This point was evident in the presence of only a single significant correlation between personality and average cortisol. Also, if personality were related to the stable component of cortisol variance, personality-cortisol correlations would be expected to be constant over the course of basic training. This expectation was not met. The second important fact was that the observed variation in personality-cortisol correlations was not consistent with expectations derived from common stress research hypotheses. Specifically, cortisol measured under stress at the first blood draw was not related to personality, while cortisol measured under the relatively low stress conditions at the third blood draw was related to personality.

The SEMs focused on separating the cortisol variance attributable to stable individual differences from the remaining cortisol variance. These analyses were based on the general principle outlined by Kraemer (1975) that biological measures typically are mixtures of variance attributable to stable differences and situational reactions. Separating the two sources of variance can be critical for the appropriate interpretation of associations between biological measures and other variables.

Structural Models. Basic SEMs combined a latent trait assessment of stable cortisol differences with manifest measures of personality as follows:

a. The stable component of cortisol (referred to hereafter as "chronic cortisol differences" to reflect the temporal stability of the differences) was assumed to be a constant source of variance over the course of basic training. Chronic cortisol differences therefore were operationalized as a latent trait with an equal influence on all three cortisol measurements. The equality constraint was justified conceptually by the idea that basal values do not change rapidly and empirically by the evidence that all pairwise correlations between cortisol measurements were essentially constant within each sample.

b. The residual variance in each cortisol measurement was assumed to be an index of reactions to the circumstances in training specific to the time of that measurement. This variance is referred to below as "disturbance variance" rather than "error variance". The choice of labels was intended to emphasize that the residual cortisol variance typically is a composite. This variance combines systematic variance arising from individual differences in reactions to the situation with variance generated by random influences on the measures (James, Mulaik, & Brett, 1982).

c. Personality was measured by latent traits defined to be equal to the observed personality scores by fixing measurement error for the indicators at zero. There was one such trait for each personality measure, so the dimensional model included five traits and the typological model included two traits.

SEM evaluations involved a sequence of comparisons which began with a null model, then compared several alternative substantive models. The sequence was:

a. The null model estimated factor loadings for the cortisol measures, factor loadings for the personality measures, and correlations between the personality measures. All other model parameters were fixed at zero. The latent traits were scaled by fixing the variance of each latent variable at 1.00.

b. The null model was fitted separately to the data from each sample. The changes that would occur if constrained parameters were estimated freely from the data (cf., Joreskog & Sorbom, 1989) were examined. Parameters changes with the same sign in both samples were identified for further consideration.

c. Modification indices (cf., Joreskog & Sorbom, 1989) for the constrained parameters retained from (b) were examined to determine whether the cumulative evidence from the two samples was sufficient to reject the hypothesis that the observed changes were the product of chance. First, the two modification indices were added to produce a combined chi-square based on independent samples (Hays, 1963, p. 341). This pooled chi-square provided one estimate of significance for the expected improvement in fit from freeing each constrained parameter. Second, the significance for each chi-square was determined separately in each sample. The method of adding probabilities (Rosenthal, 1978) then was applied to obtain a pooled significance level. This second procedure ensured that model modifications were not based on a very large modification index in one of the two samples. Cumulatively significant ($p < .05$) associations were retained for the next analysis step.

d. Those parameters meeting the significance criteria were freed one at a time to determine the actual change in the fit of the model to the data. The final model was based on the cumulative significance of the *t*-values for the freed parameters on entry into the model.

This sequence of tests was designed to emphasize replication of effects across samples over simple averaging of effects. This emphasis was intended to restrict attention to those relationships that met at least minimal standards for replication in the present study because replication of effects is more essential to aggregation of scientific evidence than is the significance of individual estimates for parameters in a single sample.

Results for Dimensional Models. The procedures just described identified reliable relationships between agreeableness and the residual cortisol variance for the midpoint in training and between conscientiousness and the residual for the cortisol measurement at the end of training. In each case, the analyses indicated that two possible modifications of the null model would result in comparable improvements in the fit of the model to the data. One approach would be the addition of a nonzero loading for the cortisol measure on the latent trait defined by the personality measure in the null model. The second approach was to add a correlation between the personality measure and the cortisol disturbance term. While this latter approach may seem unorthodox on first consideration, it is the SEM equivalent of correlating the manifest personality measurement with a residualized gain assessment of cortisol response. Models incorporating both types of modification were compared and found to yield comparable fits to the data.

The disturbance term model was adopted for conceptual parsimony. Cortisol is sensitive to many stimuli, including a range of psychosocial stimuli. The present results suggest that in some situations cortisol sensitivity may be contingent on one personality trait and in other situations on a different personality trait. If personality traits are stable across time, this situational contingency of cortisol secretion makes it illogical to regard cortisol as a personality indicator. The alternative of treating cortisol disturbance terms as an indices of responses to particular situational stimuli that are contingent on personality attributes provides a more parsimonious interpretation of cortisol values. As considered in the discussion, this perspective on cortisol makes sense in the context of current personality theory and stress models. For this reason, the correlated disturbance model was adopted.

The covariation of agreeableness with the Draw 2 cortisol disturbance and agreeableness was substantial in both samples (Sample 1, chi-square = 4.06, $p < .044$; Sample 2, chi-square = 4.67, $p < .031$). The pooled chi-square was statistically significant (chi-square = 8.73, $p < .013$). Adding probabilities also indicated a statistically significant result ($p < .003$). With the two samples combined for a single analysis, the improvement in fit from removing the constraint on this parameter was significant (chi-square = 8.01, $p < .005$).

Similar evaluations of the covariation between Draw 3 disturbance and conscientiousness indicated a significant improvement in fit in the first sample (chi-square = 4.14, $p < .042$), but a smaller improvement in the second sample (chi-square = 1.09, $p < .297$). The pooled probability estimates indicated marginal significance whether generated by the cumulative chi-square (chi-square = 5.23, $p < .074$) or the sum of the probabilities ($p < .057$). However, when the two samples were combined, a substantial improvement in fit resulted from adding the relationship between conscientiousness and Draw 3 cortisol disturbance to the model after the agreeableness-Draw 2 cortisol disturbance (chi-square = 13.33, $p < .001$).

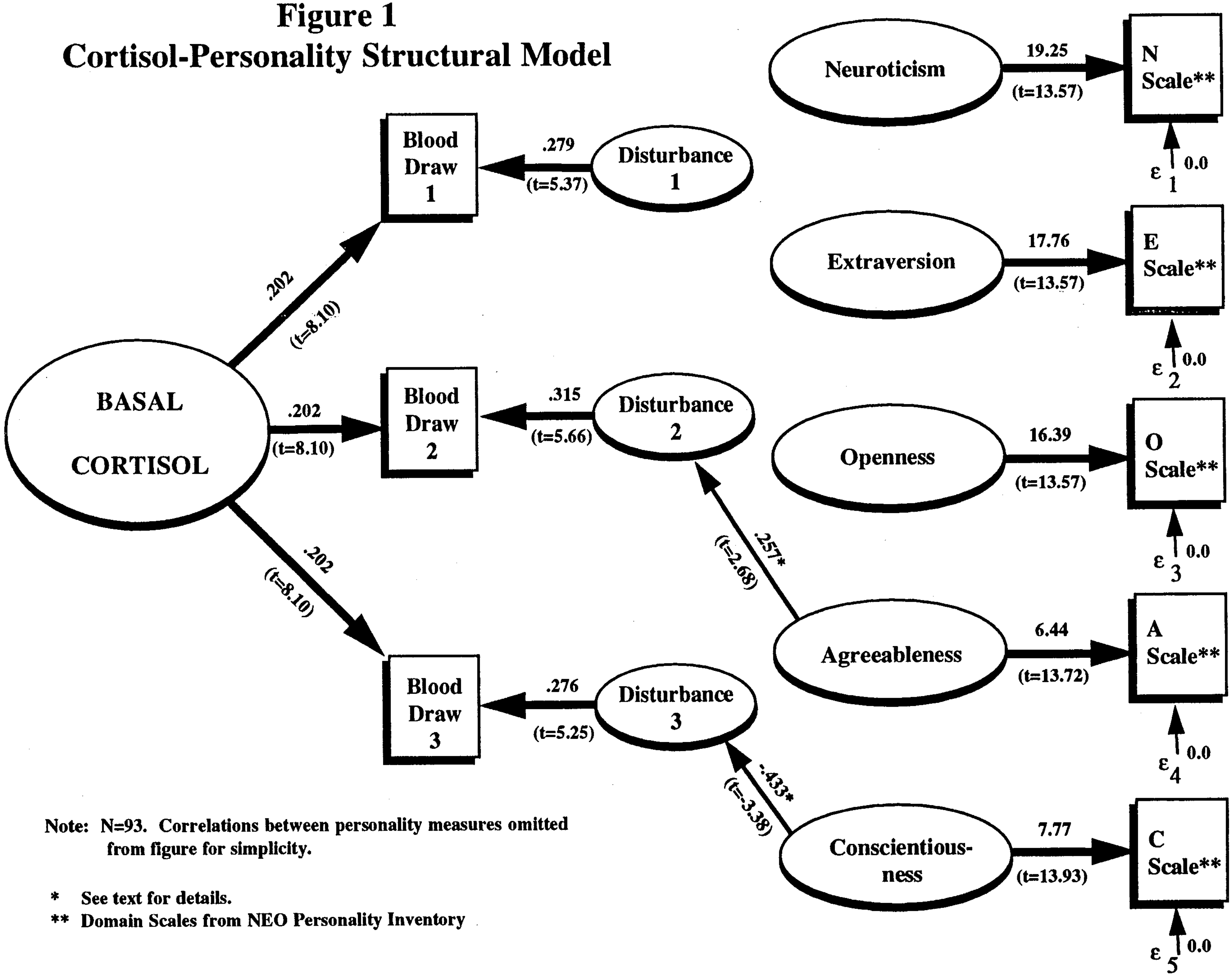
Results for the Typological Model. Reactivity was positively related to the cortisol disturbance at the end of training. The significance of the modification indices for this relationship depended on the choice of combinatorial statistics (Sample 1, chi-square = 2.77, $p < .096$; Sample 2, chi-square = 2.59, $p < .108$; combined chi-square = 5.36, 2 df, $p < .069$; adding probabilities, $p < .021$). However, freeing the constraint on the residual produced estimates with $t = 1.61$ in the first sample and $t = 1.58$ in the second sample, so the method of adding t-values indicated that the cumulative trend was significant ($z = 2.25$, $p < .013$).

Comparison of Dimensional and Typological Models. The SEMs supported the dimensional model over the typological model. The typological model produced one significant association between personality and cortisol at the end of training if the combined t-test is the criterion for significance. By the same criterion, the dimensional model produced two replicable associations, one in the middle of training and one at the end. The typological model, therefore, was inferior to the dimensional model with regard to the range of situations for which it predicted cortisol.

Replicated Personality Cortisol Model

Figure 1 presents the structural model for the replicated dimensional findings. The latent traits for residual cortisol variance controlling for the stable cortisol variance have been labeled Disturbance 1 to Disturbance 3 to emphasize that these residuals include systematic variance as well as any random affecting the cortisol measurements (cf., James, Mulaik, & Brett, 1982). The two-headed arrows in Figure 1 indicate that the disturbance terms correlate with personality.[1] As indicated, high scores on agreeableness were associated with higher cortisol near the middle of training ($r = .257$) while high scores on conscientiousness were associated with lower cortisol near the end of training ($r = -.433$).

Figure 1
Cortisol-Personality Structural Model



Note: N=93. Correlations between personality measures omitted from figure for simplicity.

* See text for details.
** Domain Scales from NEO Personality Inventory

Discussion

These studies evaluated a stress reactivity typology with cortisol secretion as the criterion. Stress reactive recruits had higher cortisol levels at the end of military basic training compared to other recruits, but they did not differ from other recruits at the beginning or middle of training. Based on past research on basic training (see p. 7), this temporal pattern of association meant that reactivity was related to cortisol under relatively low stress conditions, but not under high stress conditions. This pattern was a qualitative replication in humans of Sapolsky's (1990a,b) observations of nonhuman primates. In that research, stress reactivity was related to biological markers only in the absence of major stressors, such as drought or disruption of the social hierarchy.

Despite some support for the stress reactivity model, the overall research results supported a dimensional approach to personality for predicting cortisol. The examination of dimensional personality correlates of cortisol was included in the study to contrast stress reactivity with a logical competing model of personality. This alternative model was expected to be ineffective in predicting cortisol based on weak and/or inconsistent associations in past research. In fact, dimensional personality measures were reliable correlates of cortisol in the present samples. Agreeableness was reliably related to higher cortisol secretion in the middle of training, and conscientiousness was reliably related to lower cortisol secretion at the end of training. The dimensional model therefore was preferable to the typological model because it predicted cortisol over a wider range of conditions.

Why was it possible to identify reliable dimensional correlates of cortisol in the present study when it has been difficult to do so in the past? The presence of a standard sequence of important real-life adaptive challenges in basic training may be the key. Personality effects are most readily detected when stimulus conditions are standardized. Standardization reduces the variance attributable to situational factors, thus accentuating variance due to individual differences (Golding, 1975). The standardized challenges of training probably restrict stimulus conditions more than would be the case in the typical survey study design for studying personality and cortisol. Recruits live by a standardized training schedule. Thus, recruits rise at the same time of day, eat comparable meals, participate in comparable physical activities, go to the same classes, face the same deadlines, and so on. This consistency occurs not only for recruits in the same training company, but also for recruits in different training companies because they all follow the same training schedule. While some differences almost certainly do occur because of differences in the leadership style practiced by different Company Commanders or due to unforeseen events that require schedule modifications, recruits observed at the same point in basic training should be facing more similar situations than a random sample of people from almost any other population. People in the general populations differ with regard to times of rising, mealtimes, work schedules, recent life events, and so forth. Thus, it is extremely unlikely any pair of individuals in the population at large will have profiles of activities and stress that match as closely comparable as the profiles for a pair of recruits at the same point in basic training. At the same time, basic training is a real-life situation which has significant consequences for the individual and which gives the person time to adjust to substantial demands on his adaptive abilities. These circumstances contrast distinctly with transience and relative insignificance of laboratory studies.

The methods used to quantify stress effects also differed from typical practices. Analyses typically rely on a single measurement, the average of several measurements, or the difference between two measurements. These procedures do not provide clear isolation of chronic differences in cortisol and responses to specific situations. A single measure clearly is a mixture of both sources of variance (Kraemer, 1975). An average will emphasize differences in chronic cortisol level because this is the common source of variance in the measures (Lord & Novick, 1968). A difference score will reflect variance attributable to both situations being contrasted. The results in the present samples indicate that personality is not reliably related to chronic cortisol differences, so this source of nuisance variance should be controlled if possible.

The present results also indicate that individual personality traits predict cortisol only in specific situations. When considering a correctly chosen personality trait, therefore, any such difference measure of cortisol response is at best a composite of predictable variance and some inherently unpredictable variance.[2] The latter variance component will reduce the size of observed correlations. In effect, standard analysis procedures employ cortisol criteria that mix potentially predictable variance with inherently unpredictable variance. The SEMs in this paper separated chronic differences from acute cortisol variance and employed residual variance indicators that were specific to a particular point in basic training rather than being a composite of variance associated with two points in time. The unique combination of stimulus standardization and structural equation modeling analysis procedures may have been necessary conditions for identifying reliable associations between personality and cortisol.

Why were none of the personality variables related to cortisol at the beginning of training? One answer is that personality is expressed in behavior only to the extent that situational constraints permit (Kenrick & Funder, 1988). Adaptive demands in high stress conditions may involve a situational constraint in the sense that these demands can elicit responses from all or nearly all people, regardless of personality. If so, personality would not be expected to predict cortisol secretion in situations such as the beginning of basic training. At the end of basic training, the social environment has stabilized, and the challenges of training have been met. These conditions may provide the type of psychosocial context in which personality influences cortisol levels. Generalizing this argument to theoretical terms in the stress lexicon, personality may predict cortisol in the presence of daily hassles (Kanner, Coyne, Schaeffer, & Lazarus, 1988) but not when major life changes occur (Holmes & Rahe, 1967)[3].

Why do different personality variables predict at different times? The answer to this question may lie in the fact that although basic training provides a standardized series of challenges to recruits, the specific challenges change across time (Bourne, 1967; Janis, 1945; Maskin & Altman, 1943; Zurcher, 1968). If personality differences are expressed only when situations activate the component psychological processes comprising those traits (Tellegen, 1991), the temporal pattern of correlations could be explained by assuming that conditions near the middle of basic training made agreeableness salient, while conditions near the end of training made conscientiousness salient. While past descriptions of basic training might confirm this speculation, no attempt at verification is offered here given the risk of hindsight bias in looking for the key elements of different parts of training. Instead, it is noted that the speculation is consistent with both personality theory and person-environment fit models of stress (e.g., Caplan, Cobb, French, Harrison, & Pinneau, 1975).

The concept of boundary conditions provides an integrating framework for the observations regarding the temporal pattern of correlations between personality and cortisol. "Boundary conditions" refers to the idea that personality will predict behavior, including endocrine responses, only when situational constraints permit expression of individual differences. Stress research often may focus on extremely demanding situations where personality is of limited importance, but these relatively rare situations may be less important for overall health and well-being than are the wear-and-tear of everyday stresses. Some models of personality postulate that different personality attributes are relevant depending on the level of stress (Haan, 1977). For example, coping concepts apply under conditions of mild challenge, but defense mechanisms are relevant when challenges become more extreme. If the interpretation of the present results is correct, defining the types of stimuli and the range of intensities relevant to various personality attributes is a relatively neglected area in stress research and for personality theory.

The specific personality constructs that were central to the present findings should be of interest in testing the general hypotheses sketched above. For example, the association between conscientiousness and lower cortisol response to presumed daily hassles in training reinforces the importance of obtaining a better understanding of this personality variable in relation to stress. Other evidence already links conscientiousness to greater longevity (Friedman et al., 1993), more adaptive coping (McCrae & Costa, 1986; Vickers et al., 1989), and positive health behaviors (Booth-Kewley & Vickers, 1994). Agreeableness also is linked to health behaviors (Booth-Kewley & Vickers, 1994) and to Type A Behavior Pattern (Costa, Stone, McCrae, Dembroski, & Williams, 1987). However, the most important aspect of the findings may be the situational contingency of the personality correlates of cortisol. This contingency is a reminder that the general framework provided by the five-factor personality model is useful for ensuring adequate coverage of important personality domains in stress and health research (cf., Marshall, Wortman, Vickers, Kusulas, & Hervig, 1991).

Should the stress reactivity typology be studied further in humans? Several reasons for an affirmative answer are suggested by the present findings. First, the advantage of a typology over a dimensional model may be hard to detect even when a typology is the true model (Grove, 1991), so a single study is insufficient reason to reject the model. Second, the relative utility of dimensional and typological models may depend on the criterion. Dimensional models may be most effective in predicting acute responses to specific stimuli, while typological models are most effective in predicting the outcome of person-situation interaction processes extending across time. This criterion-based explanation could reconcile the relative weakness of the stress reactivity typology as a predictor of cortisol in the present study with the typology's apparent utility in predicting attrition from basic training (Vickers et al., 1991; Vickers et al., 1993). Third, the stress reactivity typology links studies of human cortisol response to stress to a productive model of nonhuman primate stress responses. This linkage can generate novel hypotheses, including the typological approach explored here, and/or provide qualitative replication of important findings (e.g., the absence of personality-cortisol relationships under conditions of high stress). Fourth, further study of the typology in humans may improve the characterization of stress reactivity in nonhuman primates. The use of a typology is recommended for psychometric reasons (Bolig, Price, O'Neill, & Suomi, 1992). Nonhuman primates can be rated on dimensions (Stevenson-Hinde, Stillwell-Barnes, & Zunz, 1980; Stevenson-Hinde & Zunz, 1978) that discriminate reactive from resistant animals (Bolig et al., 1992). The present findings suggest that it may be more productive to improve the rating process than to substitute a typology. Cumulatively, these arguments point to the potential for bidirectional interplay between nonhuman and human primate research on stress reactivity. The payoff from this interplay should be integrated models of stress-related health problems.

All of the preceding suggestions might be objected to on the grounds that they are based on data from just two studies of a limited segment of the population conducted in a single setting. Caution in generalizing from such a limited data base is appropriate, particularly when key arguments were introduced post hoc. While caution is appropriate, dismissing the proposed interpretations as being based on chance events would be inappropriate. Statistically, one might argue that the number of significance tests performed allowed capitalization on chance, but the analyses were designed to emphasize replication of effects over significance testing. Because 15 residuals were considered (5 personality dimensions with 3 residuals), a Bonferroni adjustment (Dunn, 1961) would set the significance level for individual tests at $p < .0033$ to maintain an experiment-wide error rate of $p < .05$. Both personality-cortisol relationships shown in Figure 1 exceeded this criterion for at least one of the significance tests reported in this study (cf., pp. 21-22), but both also fell short of the criterion by other tests. Given that some uncertainty exists in determining the exact significance level for the findings, the significance tests are regarded here as establishing that the observed relationships have a low, but distinctly nonzero, probability of occurring by chance if no association exists. This observation, coupled with corroboration of basic observations reported here from other research, supports the assertion that the model in Figure 1 is plausible. Relevant empirical evidence from other research includes the existence of stable individual differences in cortisol (Higley, Suomi, & Linnoila, 1992; Tennes & Kreye, 1985) and the presumed effects of stress level on personality-cortisol correlations (Sapolsky, 1990a,b). Other elements of the interpretations are merely applications of theoretical principles from personality and stress research to the present data. Collectively, these considerations make the proposed interpretations of the data plausible as general statements about the relationship between personality and cortisol.

The preceding observations have significant implications for stress theories. Typological and dimensional models should coexist, as suggested by Meehl (1992), at least until more definitive bases for choosing between them are available. Both stimulus intensity and stimulus quality must be considered explicitly to determine when and where personality will predict behavioral responses to stress. Stimulus intensities may have to exceed a threshold to elicit responses, but still be weak enough to permit the expression of personality differences. Stimulus quality refers to differences in the significance of stimuli to the individual. Stimulus quality must be considered to determine which personality attributes are salient in a particular setting. Careful analysis of response variables is needed to isolate those variance components relevant to personality. Effective personality-stress research requires designs based on careful situational analyses to identify circumstances that expose different people to similar stimuli, measurement of relevant personality attributes based on the stimulus situation, and longitudinal research designs to isolate sources of nuisance variance in the response variables and to observe adaptive trends. None of these requirements is novel, but the principles involved are often neglected.

In summary, the present finding that specific personality variables are related to cortisol under specific social conditions is plausible in the context of other research and current theories. Combining insights from the empirical stress reactivity and behavioral inhibition literatures (Higley & Suomi, 1989; Kagan et al., 1992; Sapolsky, 1990a,b) with theoretical principles from personality theory and analysis procedures appropriate for testing alternative hypotheses holds promise of significantly enhancing our understanding of the role of personality in stress responses. This wedding of empirical evidence, theory, and analysis should help provide more interpretable results than are obtained from the typical psychological study (Meehl, 1990). Failure to consider the relevant points can be expected to lead to further accumulation of variable results suggesting weak or nonexistent relationships between personality and cortisol (Dabbs & Hopper, 1990).

References

Anderson, S., Auquier, A., Hauck, W. W., Oakes, D., Vandaele, W., & Weisberg, H. I. (1980). Statistical methods for comparative studies. NY: Wiley.

Ballenger, J. C., Post, R. M., Jimerson, D. C., Lake, C. R., Murphy, D. L., Zuckerman, M., & Cronin, C. (1983). Biochemical correlates of personality traits in normals: An exploratory study. Personality and Individual Differences, 4, 615-625.

Barrick, M. R., & Mount, M. K. (1991). The Big Five personality dimensions and job performance: A meta-analysis. Personnel Psychology, 44, 1-26.

Bloch, S., & Brackenridge, C. J. (1972). Psychological, performance, and biochemical factors in medical students under examination stress. Journal of Psychosomatic Research, 16, 25-33.

Block, J. (1971). Lives through time. Berkeley, CA: Bancroft.

Bohnen, N., Nicolson, N., Sulon, J., & Jolles, J. (1991). Coping style, trait anxiety and cortisol reactivity during mental stress. Journal of Psychosomatic Research, 35, 141-147.

Bolig, R., Price, C. S., O'Neill, P. L., & Suomi, S. J. (1992). Subjective assessment of reactivity level and personality traits of rhesus monkeys. International Journal of Primatology, 13, 287-306.

Booth-Kewley, S., & Vickers, R. R., Jr. (1994). Associations between major domains of personality and health behavior. Journal of Personality, 62, 281-298.

Bourne, P. G. (1967). Some observations on the psychosocial phenomena seen in basic training. Psychiatry, 30, 187-196.

Brandtstadter, J., Baltes-Gootz, B., Kirschbaum, C. & Hellhammer, D. (1991). Developmental and personality correlates of adrenocortical activity as indexed by salivary cortisol: Observations in the age range of 35 to 65 years. Journal of Psychosomatic Research, 35, 173-185.

Brier, A., Albus, M., Pickar, D., Zahn, T. P., Wolkowitz, O. M., & Paul, S. M. (1987).

Controllable and uncontrollable stress in humans: Alterations in mood and neuroendocrine and psychophysiological function. American Journal of Psychiatry, 144, 1419-1425.

Caplan, R. D., Cobb, S., French, J. R. P., Jr., Harrison, R. V., & Pinneau, S. R., Jr. (1975). Job demands and worker health (HEW Publication No. NIOSH 75-160). Washington, DC: U.S. Government Printing Office.

Chodzko-Zajko, W. J., & O'Connor, P. J. (1986). Plasma cortisol, the dexamethasone suppression test and depression in normal adult males. Journal of Psychosomatic Research, 30, 313-320.

Costa, P. T., Jr., & McCrae, R. R. (1985). The NEO Personality Inventory manual. Odessa, FL: Psychological Assessment Resources.

Costa, P. T., Jr., & McCrae, R. R. (1992). The NEO PI-R manual. Odessa, FL: Psychological Assessment Resources.

Costa, P. T., Jr., McCrae, R. R., & Dye, D. A. (1991). Facet scales for Agreeableness and Conscientiousness: A revision of the NEO Personality Inventory. Personality and Individual Differences, 12, 887-898.

Costa, P. T., Jr., Stone, S. V., McCrae, R. R., Dembroski, T. M., & Williams, R. B. (1987). Hostility, agreeableness-antagonism, and coronary heart disease. Holistic Medicine, 2, 161-167.

Dabbs, J. M., Jr., & Hopper, C. H. (1990). Cortisol, arousal, and personality in two groups of normal men. Personality and Individual Differences, 11, 931-935.

Datel, W. E., & Engle, E. O. (1966). Affect levels in another platoon of basic trainees. Psychological Reports, 19, 407-412.

Datel, W. E., Engle, E. O., & Barba, M. A. (1966). Affect levels in a company of basic trainees. Psychological Reports, 19, 903-909.

Digman, J. M. (1990). Personality structure: Emergence of the five-factor model. Annual Review of Psychology, 41, 417-440.

Dunn, O. J. (1961). Multiple comparisons among means. Journal of the American Statistical Association, 56, 52-64.

Friedman, H. S., Tucker, J. S., Tomlinson-Keasey, C., Schwartz, J. E., Wingard, D. L., & Criqui, M. H. (1993). Does childhood personality predict longevity? Journal of Personality and Social Psychology, 65, 176-185.

Golding, S. L. (1975). Flies in the ointment: Methodological problems in the analysis of the percentage of variance due to persons and situations. Psychological Bulletin, 82, 278-288.

Grove, W. M. (1991). When is a diagnosis worth making? A statistical comparison of two prediction strategies. Psychological Reports, 68, 3-17.

Haan, N. (1977). Coping and defending: Processes of self-environment organization. NY: Academic Press.

Hays, W. L. (1963). Statistics for Psychologists. NY: Holt, Rinehart, & Winston.

Heise, D. R. (1969). Separating reliability and stability in test-retest correlations. American Sociological Review, 34, 93-101.

Higley, J. D., & Suomi, S. J. (1989). Temperament reactivity in non-human primates. In G. A. Kohnstamm, J. E. Bates, & M. K. Rothbart (Eds.), Temperament in Childhood (pp. 153-167). NY: Wiley.

Higley, J. D., Suomi, S. J., & Linnoila, M. (1992). A longitudinal assessment of CSF monoamine metabolite and plasma cortisol concentrations in young rhesus monkeys. Biological Psychiatry, 32, 127-145.

Holmes, T. H., & Rahe, R. H. (1967). The social readjustment rating scale. Journal of Psychosomatic Research, 11, 213-218.

Hytten, K, Jensen, A., & Vaernes, R. (1989). Effects of underwater escape training-A psychophysiological study. Aviation, Space, and Environmental Medicine, 60, 460-464.

James, L. R., Mulaik, S. A., & Brett, J. M. (1982). Causal analysis: Assumptions, models, and data. Beverly Hills, CA: Sage.

Janis, I. L. (1945). Psychodynamic aspects of adjustments to Army life. Psychiatry, 8, 159-176.

John, O. P. (1990). The "Big Five" factor taxonomy: Dimensions of personality in the natural language and in questionnaires. In L. A. Pervin (ed.), Handbook of Personality (pp. 66-100). NY: Guilford Press.

Joreskog, K. G., & Sorbom, D. (1989). LISREL VII (Second Edition). Chicago: SPSS, Inc.

Kagan, J. (1989). Temperamental contributions to social behavior. American Psychologist, 44, 668-674.

Kagan, J., Reznick, J. S., & Snidman, N. (1986). Temperamental inhibition in early childhood. In R. Plomin & J. Dunn (Eds.), The study of temperament: Changes, continuities, and challenges (pp. 53-67). Hillsdale, NJ: Erlbaum.

Kagan, J., Reznick, J. S., Snidman, N., Gibbons, J., & Johnson, M. O. (1988). Childhood derivatives of inhibition and lack of inhibition to the unfamiliar. Child Development, 59, 1580-1589.

Kagan, J., Snidman, N., & Arcus, D. M. (1992). Initial reactions to unfamiliarity. Current Directions in Psychological Science, 1, 171-174.

Kanner, A. D., Coyne, J. C., Schaefer, C., & Lazarus, R. S. (1981). Comparison of two modes of stress measurement: Daily hassles and uplifts versus major life events. Journal of Behavioral Medicine, 4, 1-39.

Kenrick, D. T., & Funder, D. C. (1988). Profiting from controversy: Lessons from the person-situation debate. American Psychologist, 43, 23-34.

Kraemer, H. C. (1975). Individual and ecological correlation in a general context (Tech. Rep. Series No. 103A). Palo Alto, CA: Stanford Medical School, Stanford University.

LaRocco, J. M., Ryman, D. H., & Biersner, R. J. (1977). Life history and mood as predictors of adjustment in Navy recruit training. Journal of Community Psychology, 5, 46-51.

Lord, F. M., & Novick, M. R. (1968). Statistical theories of mental test scores. Reading, MA: Addison-Wesley.

Marshall, G. N., Wortman, C. B., Vickers, R. R., Jr., Kusulas, J. W. & Hervig, L. K. (1991). Using the five-factor model of personality as a framework for guiding personality-health research (Tech. Rep. No. 91-36). San Diego, CA: Naval Health Research Center.

Maskin, M.H., & Altman, L.L. (1943). Military psychodynamics: Psychological factors in the transition from civilian to soldier. Psychiatry, 6, 263-269.

McCrae, R. R., & Costa, P. T., Jr. (1986). Personality, coping, and coping effectiveness in an adult sample. Journal of Personality, 54, 385-405.

Meehl, P. E. (1990). Why summaries of research on psychological theories are often uninterpretable. Psychological Reports, 66, 195-244.

Meehl, P. E. (1992). Factors and taxa, traits and types, differences of degree and differences in kind. Journal of Personality, 60, 117-174.

Moss, H. B., Yao, J. K., & Panzak, G. L. (1990). Serotonergic responsivity and behavioral dimensions in antisocial personality disorder with substance abuse. Biological Psychiatry, 28, 325-338.

Rahe, R. H., Karson, S., Howard, N. S., Rubin, R. T., & Poland, R. E. (1990). Psychological and physiological assessments on American hostages freed from captivity in Iran. Psychosomatic Medicine, 52, 1-16.

Rose, R. M., Poe, R. O., & Mason, J. W. (1968). Psychological states and body size as determinants of 17-OHCS excretion. Archives of Internal Medicine, 121, 406-413.

Rosenthal, R. (1978). Combining results of independent studies. Psychological Bulletin, 85, 185-193.

Salmon, P., Pearce, S., Smith, C. C. T., Manyande, A., Heys, A., Peters, N., & Rashid, J. (1989). Anxiety, Type A personality and endocrine responses to surgery. British Journal of Clinical Psychology, 28, 279-280.

Sapolsky, R. M. (1990a). Adrenocortical function, social rank, and personality among wild baboons. Biological Psychiatry, 28, 862-878.

Sapolsky, R. M. (1990b). Stress in the wild. Scientific American, 262, 116-123.

SPSS, Inc. (1988). SPSS-X User's Guide (3rd ed.). Chicago: SPSS, Inc.

Steiger, J. H. (1980). Tests for comparing elements of a correlation matrix. Psychological Bulletin, 87, 245-251.

Stevenson-Hinde, J., Stillwell-Barnes, R., & Zunz, M. (1980). Subjective assessment of rhesus monkeys over four successive years. Primates, 21, 66-82.

Stevenson-Hinde, J., & Zunz, M. (1978). Subjective assessment of individual rhesus monkeys. Primates, 19, 473-482.

Tellegen, A. (1991). Personality traits: Issues of definition, evidence and assessment. In D. Cicchetti & W. Grove (Eds.), Thinking clearly about psychology: Essays in honor of Paul Everett Meehl (pp. 10-35). Minneapolis: University of Minnesota Press.

Tennes, K., & Kreye, M. (1985). Children's adrenocortical responses to classroom activities and tests in elementary school. Psychosomatic Medicine, 47, 451-460.

Van Cauter, E., & Aschoff, J. (1989). Endocrine and other biological rhythms. In L. J. DeGroot, G. M. Besser, G. F. Cahill, Jr., J. C. Marshall, D. H. Nelson, W.D. Odell, J. T. Potts, Jr., A. H. Rubenstein, & E. Steinberger (Eds.), Endocrinology (2nd ed., Vol. 3). (pp. 2658-2705). Philadelphia: W. B. Saunders.

Vickers, R. R., Jr. (1988). Effectiveness of defenses: A significant predictor of cortisol excretion under stress. Journal of Psychosomatic Research, 32, 21-29.

Vickers, R. R., Jr. (1991). Stress reactivity: Five-factor representation of a psychobiological typology (Tech. Rep. No. 91-26). San Diego: Naval Health Research Center.

Vickers, R. R., Jr., Hervig, L. K., & Bischoff, C. W. (1991). Stress reactivity: Prediction of attrition following medical problems in basic training (Tech. Rep. No. 91-48). San Diego, CA: Naval Health Research Center.

Vickers, R. R., Jr., Hervig, L. K., Levy, S. M., Whiteside, T. M., & Herberman, R. B. (in preparation). Psychological correlates of natural killer cell activity in military recruits (Technical report). San Diego, CA: Naval Health Research Center.

Vickers, R. R., Jr., Hervig, L. K., Wallick, M. T., Poland, R. E., & Rubin, R. T. (1987). Psychological correlates of cortisol excretion in normal individuals under stress (Tech. Rep. No. 87-1). San Diego, CA: Naval Health Research Center.

Vickers, R. R., Jr., Walton, E. P., Hervig, L. K., & Conway, T. L. (1993). Stress reactivity and attrition in two basic training populations (Tech. Rep. No. 93-39). San Diego, CA: Naval Health Research Center.

Vickers, R. R., Jr., Kolar, D. W., & Hervig, L. K. (1989). Personality correlates of coping with military basic training (Tech. Rep. No. 89-3). San Diego, CA: Naval Health Research Center.

Zurcher, L. A., Jr. (1968). The Naval Recruit training Center: A study of role assimilation in a total institution. Sociological Inquiry, 31, 85-98.

Footnotes

[1]The estimated covariances between cortisol disturbance terms and personality dimensions were computed using the following formula:

$$r_{pd} = Cov_{pd}/s_p s_d$$

where r is a correlation, p indicates the relevant personality dimension, d indicates the relevant disturbance term, s indicates standard deviation, and "cov" refers to covariance. The s values for disturbance terms were the residual variances for the respective cortisol measures.

These computations apply a standard formula for correlation given an estimate of the standard deviation of the residual cortisol at each point in the study. Chronic cortisol differences were not related to personality, so any observed covariation of personality and cortisol reflected associations between personality and the effects of the situational influencing cortisol at that point in training. The variance of those situational effects was estimated by subtracting the variance arising from chronic cortisol differences from the total variance for the specific cortisol measurement of interest. The square root of the residual variance then was the estimate of the disturbance standard deviation that was inserted in the computational formula above.

[2]The composite nature of a difference score can be seen by considering values on a given day as the sum of a chronic value, a reaction to the circumstances of the day, and measurement error. Defining the chronic component as constant across time, a difference score computed between two days would be:

$$\text{Difference} = I + D1 + E1 - (I + D2 + E2) = D1 - D2 + E1 - E2$$

where the numbers "1" and "2" refer to the days in question. Given the usual definition of error as a random variate, the D1 and D2 terms are the potentially predictable components of the difference. A significant correlation could be obtained if a personality variable predicted either D1 or D2 or both. If the personality variable were related to the reactions to both days, the associations would have to have the opposite sign or they would cancel out. This propitious combination of effects will occur only by chance unless an adequate theoretical specification of the conditions under which a given personality variable will predict cortisol is combined with a valid model of situations to guide the sampling of measurement occasions to relevant situations. These prerequisites generally are lacking given the current state of stress research. Even if the requisite models were available, it would be desirable to isolate the individual components of the difference score variance to verify both theoretical personality-cortisol relationships separately. In the absence of such verification, the existence of three possible patterns of association underlying a significant correlation (i.e., to D1, D2, or both) is reason to consider those associations ambiguous. Residualized gain scores would not eliminate the ambiguity because these scores involve the same variance components. Residualized gain scores are equivalent to simple difference scores except that gain scores apply a different computation weight to one of the difference score components (Anderson et al., 1980). In general, then, theoretical and psychometric considerations make the isolation of reactions to specific situations the preferred mode for evaluating personality effects on situational reactions. The SEMs in the present study provide one method of isolating variance attributable to a specific measurement occasion (including, of course, the measurement error for that specific occasion).

[3]The situational constraint interpretation of the temporal pattern of personality-cortisol correlations is consistent with Sapolsky's (1990b) stress reactivity observations regarding the conditions under which stress reactivity predicts cortisol in nonhuman primates. However, the present study design confounds stress level with time of day. High stress measures were taken earlier in the day in both samples, so normal circadian variations in cortisol provide an alternative interpretation of the presumed stress effects on cortisol if the circadian peak occurred at 0530 to 0600 in the morning. This timing of the peak would be toward the early end of the estimated 0600 to 1000 range of times estimated for the circadian peak of cortisol (Van Cauter & Aschoff, 1989). If the true circaian peak under the conditions in basic training were near the middle of the range, the blood samples in one study would have been drawn well in advance of the peak (0600), while those in the second study would be drawn near the most likely time of the peak (0730). Circadian variation then could explain the observed differences in one sample, but not in the other. Given uncertainty about the exact timing of the circadian peak of cortisol in this population and setting, the actual degree of confounding, if any, cannot be determined from the data. The key point for consideration in connection with the situational constraint interpretation is that even if such circadian effects were present, they would not invalidate the proposed interpretation of the temporal pattern of personality-cortisol correlations. The situational constraint interpretation applies to <u>any</u> situational constraint(s), so the principle that personality differences will be related to cortisol secretion only when situational determinants of cortisol permit applies in the most general case.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
5 Apr 95

3. REPORT TYPE AND DATE COVERED
Interim Oct 93 - Sep 94

4. TITLE AND SUBTITLE
Cortisol Secretion Under Stress: Test of a Stress Reactivity Model in Young Adult Males

5. FUNDING NUMBERS
Program Element:
Work Unit Number:
ONR Reimbursable 6252

6. AUTHOR(S)
Vickers, R.R., Jr., Hervig, L.K., Poth, M. & Hackney, A.C.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Health Research Center
P. O. Box 85122
San Diego, CA 92186-5122

8. PERFORMING ORGANIZATION
Report No. 95-17

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Naval Medical Research and Development Command
National Naval Medical Center
Building 1, Tower 2
Bethesda, MD 20889-5044

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

A three-group stress reactivity typology was compared to a five-factor dimensional personality model as predictors of cortisol secretion in two samples of U.S. Navy recruits (n = 40 and n = 53) during military basic training. Initial exposure to basic training was associated with elevated cortisol levels compared to later in training. Individual differences in cortisol were moderately stable over the course of basic training, but neither personality model predicted the stable individual differences reflected in cortisol. In the typological model, stress reactive individuals showed higher cortisol at the end of training. In the dimensional model, agreeableness was associated with higher cortisol in the middle of training, and conscientiousness was associated with lower cortisol at the end of training, so the dimensional model predicted cortisol over a wider range of training conditions. These results are interpreted as consistent with a conditional person-environment fit model of stress. The model postulates that different personality attributes predict cortisol secretion when social stimuli relevant to those attributes are present. The relationships are conditional in that they are present only in a stable social situation.

14. SUBJECT TERMS
cortisol
personality
structural equation modeling
stress
basic training
military

15. NUMBER OF PAGES
34

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102