

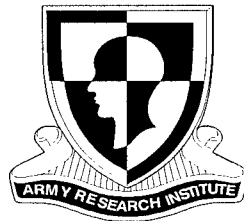
Modeling Human Performance: Effects of Personal Traits and Transitory States

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MODELING HUMAN PERFORMANCE: EFFECTS OF PERSONAL TRAITS AND TRANSITORY STATES

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Modeling Human Performance: Effects of Personal Traits and Transitory States

Introduction

In a recently published report, Gillis, Hursh, Guest, Sweetman, & Ehrlich (2000) reported the development of a Human Performance Model (HPM) for representing realistic behavior by Computer Generated Forces (CGF) Command Entities (CEs). The model as described by Gillis et al. included the effects of experience, stress, sleep, and circadian rhythm on the decision-making performance of CEs. During the writing of that report and following its completion, changes were made to the HPM that resulted in a significantly altered and slightly more elaborate implementation of the HPM. The primary purpose of this report is to document the implemented revision of the HPM, and to identify aspects of the model that may require further improvement. The software for the implemented version is available for further research/development and may be obtained by contacting the authors of this report. Another goal of the report is to provide additional detail regarding the structure and content of the HPM not found in previous descriptions of the model. This report is not meant to be a stand-alone document, but rather is an update that revises and supplements information provided in the Gillis, et al. report. Readers of this report are encouraged to first familiarize themselves with the basic model by referring to Gillis, et al.

The basic idea underlying the HPM described by Gillis et al. (2000) is that commanders start with a fixed amount of cognitive resources. These resources enable the CEs to make combat-related decisions and accomplish their missions. Cognitive resources are expended during mission performance and are replenished during periods of sleep. The amount of CE cognitive resources remaining at any given time along with stress effects are the primary determinants of CE effectiveness. The level of stress is determined by the nature of battlefield events. Battlefield events by their nature either evoke stress or build CE confidence. CE effectiveness along with performance moderators affects both combat performance and the type and quality of CE decisions. Performance moderators in the original model were experience, circadian rhythm, and time pressure.

Like the original model the revised HPM includes the effects of experience, stress, sleep, and circadian rhythm, but in addition the revised model includes the effects of intelligence, aggressiveness, and personality type. CE intelligence, experience, and aggressiveness are each classified as low, medium, or high. CE personality is assigned to one of two types: Positive Personality, or Negative Personality. Positive personality types are more resistant to the effects of stress and time pressure than are negative personality types. Stress, sleep, and circadian rhythm effects are not classified according to discrete levels, but vary along a continuum.

Table 1 lists and defines the critical variables included in the revised HPM, as well as other variables used in their computation. Table 1 also shows the range of values for each variable. Additional information about the variables and the model construction is provided in subsequent sections of this report.

Table 1

HPM Variable Definitions and Value Ranges

SYMBOL	NAME	VARIABLE DEFINITION/EXPLANATION	VALUE RANGE
α	Accumulation Rate	Rate at which performance units accumulate during sleep (increases as CE becomes more sleep deprived)	1 - 3.48
none	Adjusted Performance	A model output that reflects performance adjusted for effectiveness	.01-100
Agg	Aggressiveness	A behavioral modifier that determines the degree to which a CE's decision incorporates risk-prone and risk-averse elements	0-100
RB	Cognitive Reservoir Resource Balance	The number of effective performance units remaining in the CE's cognitive reservoir (increased by sleep & decreased by performance)	0-2880
R	Cognitive Reservoir Resource Capacity	The number of effective performance units in a CE's cognitive reservoir when fully rested	2880
None	Confidence Building Amplitude	A number representing the degree of confidence instilled in the CE by significant combat scenario events that advance the mission	0-10
None	Decision Type 1: Correct(C) or Random(R)	A decision selected after considering all reasonable alternatives. Decisions may be Passive(P), Neutral(N), or Aggressive(A)	CP, CN, CA, RP, RN, RA
None	Decision Type 2: Primed(P) or Random(R)	A decision based on recognizing aspects of the current situation that resemble those found in previously experienced situations. Decisions may be Passive(P), Neutral(N), or Aggressive(A)	PP, PN, PA, RP, RN, RA
E	Effectiveness	A key model parameter indicating the quality of CE decision making and combat performance	0-100
Exp	Experience	A number representing the level of CE combat experience	0-100
Expcat	Experience Category	One of three categories representing low, medium, & high combat experience	1 thru 3
Int	Intelligence	A number representing the level of CE intelligence	0-100
Intcat	Intelligence Category	One of three categories representing low, medium, & high intelligence	1 thru 3
none	Lower Limit	A number that marks the maximum amount of aggressiveness that results in risk-averse courses of action	33.3
λ	Minimum Accumulation Rate	The minimum rate at which resource units accumulate during sleep (occurs when CE is fully rested)	1
None	Performance	The level of proficiency demonstrated in completing a combat scenario	7.5 - 97.5
C	Performance Circadian Rhythm	A cyclical performance moderator that varies with time of day	-7.5 - 15
None	Performance Degrade	A number that varies with effectiveness that reduces performance to produce the model output, adjusted performance	0 - 50
performance pos	Performance for Positive Personality	Performance which has been adjusted higher to account for positive personality type	8.25 - 107.25
Performance neg	Performance for Negative Personality	Performance which has been adjusted lower to account for negative personality type	6.75 - 87.5

Table 1 (continued)

HPM Variable Definitions and Value Ranges

SYMBOL	NAME	VARIABLE DEFINITION/EXPLANATION	VALUE RANGE
p	Performance Use Function	The number of performance units expended as a direct consequence performing tasks that tax the CE's physical and cognitive resources	0 - 2400*
Rand Exp	Random Experience	A random number that, depending on the level of CE experience, determines whether a decision will be a correct or random decision	0-100
randVar	Random Variable 1	A number derived from Random Variable 2 and Random Variable Degrade, later compared with Effectiveness to determine decision type	-32.5 - 142.5
randvar	Random Variable 2	A random number used to adjust Random Variable 1	0 -100
randVar degrade	Random Variable Degrade	A number computed from experience and intelligence and used subsequently to adjust Random Variable 1 up or down	11.25 - 42.5
κ	Resource Use Rate	The rate at which resource units are decreased (varies with how much combat tasks tax the CE's physical and cognitive resources)	0 -1 (set at 0.5)
s	Sleep Accumulation Function	The number of performance units accumulated as a direct result of sleep that restores the CE's physical and cognitive resources	417.6 - 569.76
none	Stress Amplitude	A number representing the intensity of the stress induced in the CE by significant combat scenario events that impede the mission	0 -10
SEA	Stress Effect Adjustment	The amount that the stress effect is adjusted to account for positive or negative personality type	-30 - 17
SE Neg Clip	Stress Effect for Negative Personality (clipped)	Limits the range of possible Adjusted Stress Effects between the values of -20 and 10 for negative personality types	-20 - 10
SE Pos Clip	Stress Effect for Positive Personality (clipped)	Limits the range of possible Adjusted Stress Effects between the values of -20 and 10 for positive personality types	-20 - 10
SE	Stress Effects	The combined effects of confidence building and stress evoking events, including the effects of time pressure	-20 - 10
ts	Time Asleep	The average minutes of sleep for the 5 days preceding a period of performance	120 - 480
ta	Time Awake	The number of minutes awake following a period of sleep	0 - 4800*
β	Time Constant	A constant used in the calculation of sleep accumulation rate	0 - .0038
None	Time Delay	The time delay between the need for a decision and the time that the decision is rendered (delay is an inverse function of effectiveness)	1 to infinity
h	Time Pressure	Aspects of the combat situation that require speedy decisions or actions (time pressure tends to increase stress and decrease performance)	1, 1.1, 1.5, 2
none	Upper Limit	A number that marks the minimum amount of aggressiveness that results in risk-prone courses of action	66.7

* Assumes that Resource Use Rate, $\kappa = 0.5$ and Cognitive Reservoir Resource Balance, $RB > \text{or} = 0$

For purposes of this discussion, the HPM may be divided into three cases: the nominal case, the positive personality case, and the negative personality case. A flow chart for the nominal case is shown in Figure 1. Additional flow charts, discussed later, represent the positive and negative personality cases. Each rectangular block in the flow charts represents a critical model variable. The values assigned to these variables are either the result of a calculation or else are determined by satisfaction of a specified set of conditions. The formulas and conditions for calculating these values are also shown in the blocks. The model formulas were taken from a spreadsheet developed for research purposes (Science Applications International Corporation, 2000). The output of each block is the value of the variable that was calculated in that block. Inputs to a block are calculated values output from other blocks and are shown as arrows pointing toward the block receiving the input. Oval-shaped blocks represent the outputs of the HPM and provide inputs to a combat simulation. Model outputs include CE Adjusted Performance, Type of Decision made by the CE, and the Time Delay in making the decision.

Nominal Case

Effectiveness

The nominal case, shown in Figure 1, will be used in explaining the variables that are common to the three HPM cases. The heart and soul of the HPM is Effectiveness. In one way or another Effectiveness affects all of the HPM outputs and, in turn, is affected by many of the model inputs and variables derived from those inputs. For explanatory purposes, we first discuss the variables that influence effectiveness. These include Stress Effects, Circadian Rhythm, Sleep, and Cognitive Resource variables. Then we will consider how effectiveness combines with the remaining variables (experience, intelligence, and aggression) to yield model outputs.

Inputs to Effectiveness

Stress Effects. Combat events include those that produce stress and those that build confidence. The amplitude of the stress or confidence building event depends on the intensity of the event. Combat events are typically performed under time pressure. Survival often depends on how quickly CEs and their units execute an action or respond to an enemy initiative. In the HPM, the amount of time pressure can be low, medium, high, or in rare cases, zero. As shown in Figure 1, Stress Effects (SE) = Confidence Building Amplitude – (Stress Amplitude * Time Pressure).

Sleep Variables. The CE's cognitive reservoir maintains a balance of effective performance units. Performance is at its peak when the CE is fully rested. Sleep, or the lack thereof, influences effectiveness indirectly by altering the number of performance units in the cognitive reservoir. The number of performance units in a CE's cognitive reservoir when fully rested is that CE's Resource Capacity (R). The number of performance units remaining at time t, the Resource Balance (RB), varies according to a sleep accumulation function (s) and a performance use function (p). The sleep accumulation function equals the time asleep multiplied by the accumulation rate

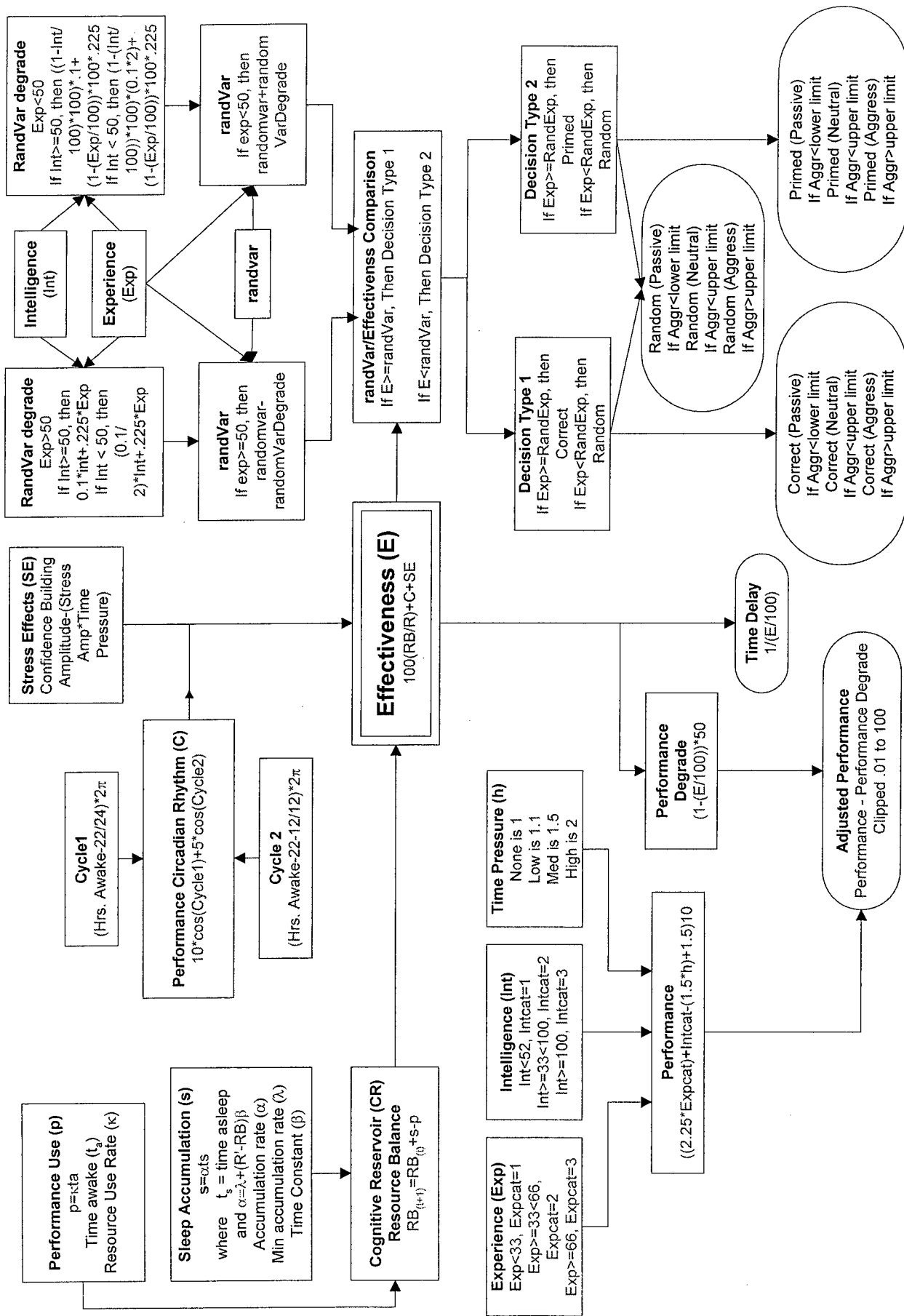


Figure 1. HPM flow chart for the nominal case.

(α), while the performance use function (p) equals the time awake multiplied by the resource use rate (κ). The sleep accumulation rate (α) increases as the CE becomes more sleep deprived. Hence short periods of sleep become more beneficial as the sleep deprivation increases. The Resource Balance is increased by minutes of sleep and decreased by minutes of performance. The Resource Balance at time $t+1$ is the sum of the Resource Balance at time t , the sleep accumulation function, and the performance use function.

Circadian Rhythm. Circadian rhythm is cyclical performance variation that is a function of time of day. In the current model circadian rhythm is calculated as a cosine function of hours awake since midnight of the previous night. The HPM assumes that all sleep periods begin at midnight. Circadian rhythm moderates CE performance by changing Effectiveness.

Computing Effectiveness

Effectiveness (E) is the sum of $(100 * \text{Resource Balance}) / \text{Resource Capacity}$, the circadian rhythm, and the stress effects (SE). As effectiveness varies with these parameters, it produces variation in the accuracy and types of decisions, the time delay before these decisions are made, and the levels of combat performance. This leads to more realistic and less predictable CE behavior than would be possible without taking these human performance moderators into account.

Decisions as Model Outputs

Decision Types. The intelligence and experience of the CE along with level of effectiveness determines whether each decision will be based on considering all reasonable alternatives (Decision Type 1) or be based on recognizing aspects of the current situation that resemble those found in previously experienced situations (Decision Type 2). Both types of decisions may be correct or random depending on CE experience. Random decisions are decisions selected randomly from a group of reasonable decision alternatives and are typically incorrect, but random selection of the correct alternative is possible. Low levels of experience are likely to produce a random decision. High levels of experience coupled with low effectiveness are likely to produce a correct Decision Type 2, while high experience and high effectiveness are likely to produce a correct Decision Type 1. CE intelligence levels also influence the type of decision, but the effects of intelligence in determining the decision type are less important than those of experience.

Note that the above discussion of decision types refers to the likelihood of various decision outcomes. The model is probabilistic in that randomly generated numbers influence CE decisions. For example, a randVar Degrade, calculated from experience and intelligence, is added or subtracted from a randomly generated number (randvar) to generate randVar, which, in turn, is compared to Effectiveness to determine if the decision is Type 1 or Type 2. Also a random value of experience (RandExp) is generated to compare with the CE experience level to determine if the decision will be a correct or a

random decision. (See the right-hand side of Figure 1 to better understand how randomness influences the decision process).

Aggressiveness. CE aggressiveness is a behavioral moderator that influences the decision process. This model uses three categories of aggressiveness: aggressive, neutral, and passive (risk averse). Aggressiveness does not determine whether the decision is correct or random, but a CE with an aggressive personality may decide on a course of action that involves more risks than a CE with a passive or neutral personality. If the level of aggressiveness is less than the lower limit (33.3), then the decision will have more passive or risk-averse elements. If the level of aggressiveness is less than the upper limit (66.7), then the decision may involve a balance of passive and aggressive elements. Finally, if the level of aggressiveness is greater than the upper limit, then the decision will include many aggressive elements.

Time Delays as Model Outputs

Decision Time Delays. Combat decisions are not rendered instantaneously. It takes time for the CE to assess the situation, consider alternate courses of action, and select a course of action. Decision time may depend on how much sleep the CE has had, the time of day, and how much stress the CE is experiencing. In this model these factors influence the latency of a decision through Effectiveness. The decision latency or time delay in minutes is given by the formula $1 / (E / 100)$, where E is Effectiveness. Hence decision time decreases as effectiveness increases.

Performance Levels as Model Outputs

Calculating Performance. The magnitude of performance is determined by experience, intelligence, and time pressure, where $\text{Performance} = ((2.25 * \text{experience category}) + \text{intelligence category} - (1.5 * \text{time pressure}) + 1.5) * 10$. The experience category is set to 1 for all experience levels less than 33, to 2 for experience levels 33 or more but less than 66, and to 3 for experience levels of 66 or more. Similarly the intelligence category is set to 1 for intelligence levels less than 52, to 2 for intelligence levels 52 or more but less than 100, and to 3 for intelligence levels of 100 or more. Time pressure values are 1 for no time pressure, 1.1 for low time pressure, 1.5 for medium time pressure, and 2.0 for high time pressure. Time pressure has detrimental effects on performance. As time pressure increases performance decreases. To some extent, high levels of experience and intelligence serve to mitigate the adverse effects of time pressure.

Adjusted Performance. Effectiveness influences performance by increasing or decreasing a performance degrade variable. $\text{Performance Degrade} = (1 - (E / 100)) * 50$. The amount by which performance is degraded decreases as effectiveness increases. Conversely, the amount of performance degradation increases as effectiveness decreases. The Performance Degrade is subtracted from calculated performance to yield Adjusted Performance. Hence, Adjusted Performance increases as effectiveness increases. Adjusted Performance, Time Delay, and Decision Type constitute the model outputs.

Positive and Negative Personality Types

Gillis et al. (2000) discuss personality type but do not include it as a component of their model. However, in the implemented version of the model, stress effects and performance are adjusted to account for personality effects in determining CE reactions to stressful events and time pressure. Negative personality types react strongly to stress-producing events and/or time pressure. Positive personality types feel confident that they are in control of the situation and exhibit much milder reactions to stressful events. Table 2 lists a combination of personality traits that represent the extremes in reacting to stress-inducing events. In reality, the extremes represented by these clusters of traits would be rare. Personality types that fall in between these extremes can be considered to have neutral personalities and are covered by the nominal case described above.

Table 2

Traits that Define Positive and Negative Personality Types

Traits Associated with Strong Reactions to Stressful Events (Negative Personality)	Traits Associated with Mild Reactions to Stressful Events (Positive Personality)
Type A Personality High Trait Anxiety Low Self Confidence Extroversion External Locus of Control	Type B Personality Low Trait Anxiety High Self Confidence Introversion Internal Locus of Control

Positive Personality Case

In the implemented model, an assumption is made with regard to CE personality type. Assuming the CE has a positive personality, the computation of the stress effect and performance is changed to reflect the influence of the positive personality type. The flowchart for the positive personality type is shown in Figure 2. Blocks that are shaded are unchanged from the nominal case and the variables represented by those blocks are calculated in the same manner as for the nominal case. Unshaded blocks indicate changes from the nominal case. The stress effect for the positive personality case is calculated by adding a positive personality adjustment to the nominal case stress value. The positive personality adjustment is equal to the absolute value of the nominal stress effect multiplied by a positive personality constant (0.7). The adjusted stress effect is then clipped between -20 and 10 and used in computing Effectiveness. Performance is calculated as in the nominal case and adjusted by the following formula: Performance (positive personality) = $1.1 * \text{nominal performance}$. The result, clipped between .01 and 100, is the performance output of the model for the positive personality case.

Negative Personality Case

Alternately, if the CE has a negative personality, the computation of the stress effect and performance are changed to reflect the influence of the negative personality type.

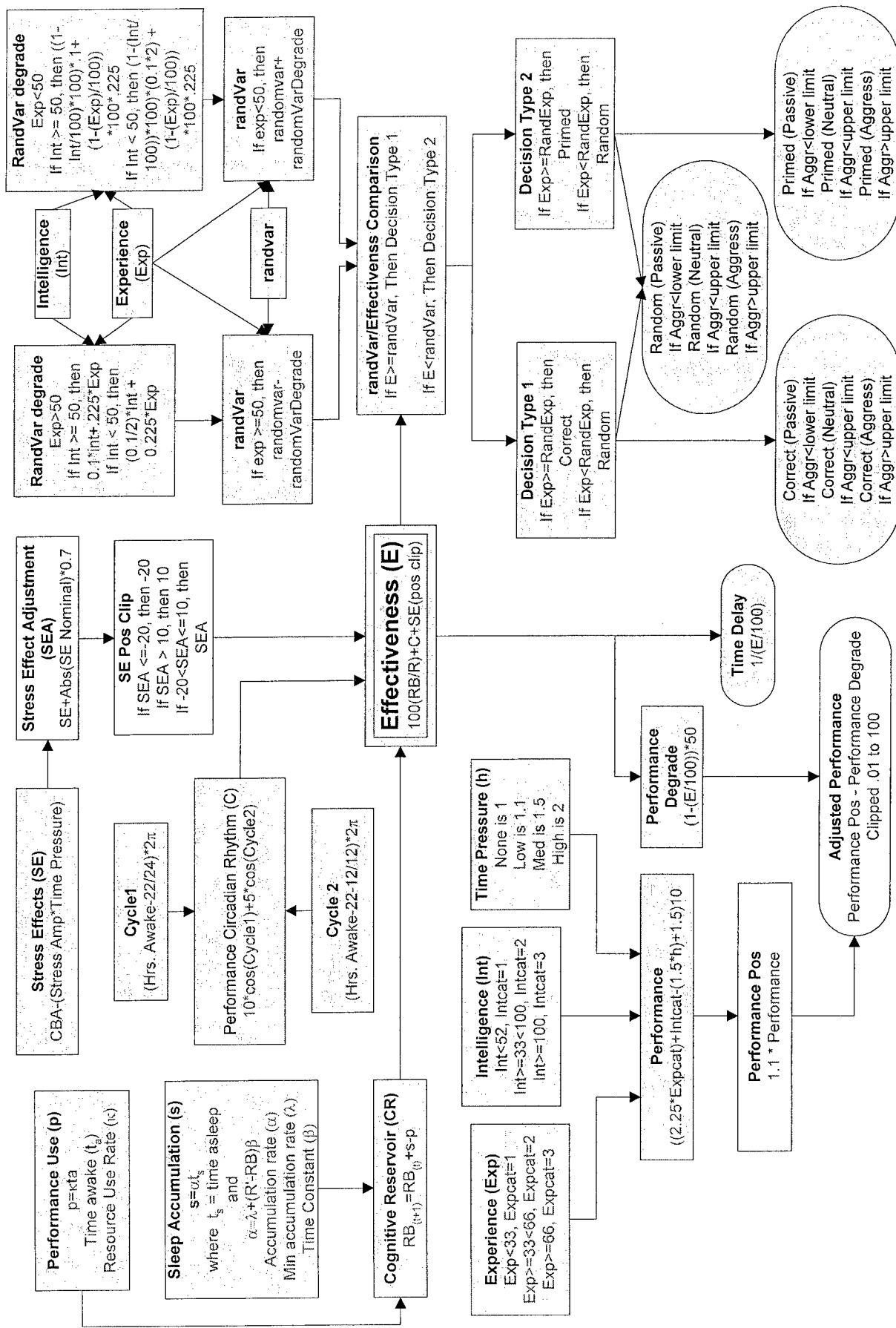


Figure 2. HPM flow chart for positive personality type.

The flowchart for the negative personality type is shown in Figure 3. Blocks that are shaded are unchanged from the nominal case and the variables represented by those blocks are calculated in the same manner as for the nominal case. Unshaded blocks indicate changes from the nominal case. The stress effect for the negative personality case is calculated by subtracting a negative personality adjustment from the nominal case stress value. The negative personality adjustment is equal to the absolute value of the nominal stress effect multiplied by a negative personality constant (0.5). The adjusted stress effect is then clipped between -20 and 10 and used in computing Effectiveness. Performance is also calculated as in the nominal case and adjusted by the following formula: Performance (negative personality) = $0.9 * \text{nominal performance}$. The result, clipped between .01 and 100, is the performance output of the model for the negative personality case.

Human Performance Model Strengths

Utilizes Data-Derived Sleep/Fatigue Model

The model is based on available empirical data buttressed by psychological theory. The modeled effects of sleep on performance are based on studies of sleep deprivation conducted by the Walter Reed Army Institute of Research (WRAIR). The WRAIR sleep model has been updated and refined to better reflect contemporary psychophysiological and performance research (Hursh & McNally, 1993). The current implementation of the model reflects further sleep model refinement, and relates hours asleep, hours awake, and circadian rhythm to cognitive performance.

Dynamic Modifiability

Combat is dynamic with dramatic shifts in the situation; therefore, emotional and cognitive factors are likely to vary as the situation changes. The current model partially accounts for changing situations by tracking changes in cognitive resources and by adjusting CE stress or confidence levels based on the nature of the combat events.

Considers Differences in Experience, Intelligence, & Personality

The role of experience in determining the type of decision under time pressure also has empirical support and strong theoretical underpinnings (Klein, 1996; 1997). This is one of the few models that incorporate naturalistic decision making in choosing a course of action. The model also reflects the interactions of experience and intelligence with stress as suggested by a study of these interactions (Locklear, Fiedler, & Powell, 1988). The model includes the effects of the positive and negative personality traits on performance. Because the data do not exist to quantify these effects precisely, the model must estimate how much these personality traits influence performance.

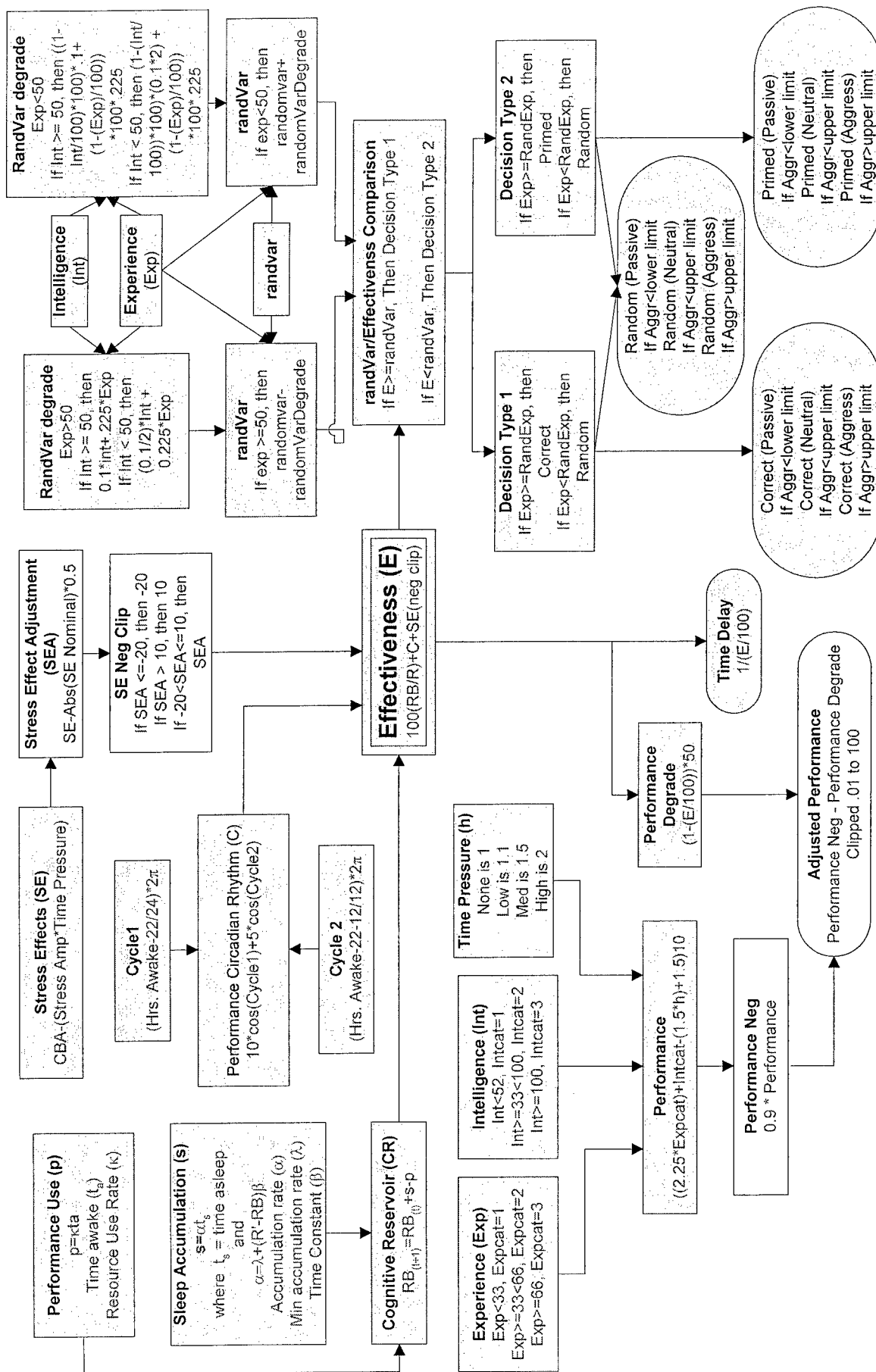


Figure 3. HPM flow chart for negative personality type.

Human Performance Model Deficiencies

Inadequate Representation of Human Emotions

Currently the model accounts for the effects of emotion on decision making and performance by keying stress effects to combat events. These events are seen as either evoking CE stress or building CE confidence. This is a very general representation of the effects of emotion on performance. In reality, combat events may generate a wide range very specific emotions. At times combatants may experience several emotions at once. When emotions conflict, one may take precedence over another. Also, at low levels, emotions may not have any effect on performance whatsoever. The current model does not recognize that there may be emotion thresholds that must be crossed before there is any effect on performance. For example, at what level will low or high morale start to influence performance? Experimentally manipulated mood has been shown to affect performance (Hirt, McDonald, & Melton, 1996), but this model does not consider mood. Arousal may induce emotions that influence performance, but this model does not consider arousal levels. Arousal levels depend on both personality and situational factors.

Simplistic Personality Representation

Personality effects are also represented in a very general manner. In this model, CEs are assigned a positive or negative personality type. Positive personality types are more resistant to the effects of stress and time pressure than are negative personality types. The model includes aggressiveness as a personality trait, but does not specifically represent other personality dimensions that have been shown to affect performance or decision making. Among these dimensions are self-confidence, stress tolerance, independent/cooperative, loyalty, and social ability.

Omits Attention, Perceptual Factors, and Situational Awareness

The model does not distinguish between the objective event and the CE's perception of the event. Incomplete information, the CE's personality traits, current emotional state and available cognitive resources could color the CE's perception. The model does not account for varying levels of attention to combat events. Situational awareness is not included in the model. Depending on attentiveness, the CE may misinterpret an event or fail to notice it. The model incorrectly assumes that the CE has complete information and fully understands the situation. If the information is incomplete, uncertainty may evoke strong emotions, producing significant effects on CE decisions and performance. Confusion during combat can lead to flawed decisions.

Does not Account for CE Goals and Expectations

The model does not consider CE or unit goals in determining levels of stress or other combat emotions. In the current model, stress or confidence building amplitude is a

sole function of the intensity of the event. However the emotional impact of an event may also depend on how it relates to CE goals and expectations. Emotions may soar when the event outcome does not match CE expectations.

More Verification and Validation Data are Needed

Little data have been collected to verify and validate the model or its components. Gillis (1998) collected C3SIM data with and without input from the HPM to verify that the HPM can modify behaviors in the C3SIM and affect the performance of computer-generated CEs. They also compared data collected from the HPM running in conjunction with C3SIM to National Training Center (NTC) data, which is based on real commander's performance and decision making. This latter comparison demonstrated that the levels of performance produced in the C3SIM by the HPM sleep deprivation component roughly corresponds to the NTC data in which the CE was similarly rested or fatigued. This constitutes a partial validation of the model. Gathering additional information about the types of correct and incorrect decisions made by real commanders in various battlefield scenarios could be used to improve the model. Similarly, quantitative data on the effects of time pressure, experience, and various traits and emotions could be compared with the values the model currently produces. Such data would permit model adjustment to better represent reality. In addition to validating the individual model components, the manner in which those components interact should be verified. For example, do CE intelligence and experience interact as prescribed by the model? Is too much or too little weight given to the various components in the model as they affect the CE's decisions?

A question that relates to, but is not synonymous with, model validity is how do we determine if the model is good enough for a specific purpose or goal. In the current case, the goal is to moderate the behavior of a CGF so that it exhibits the behavioral characteristics and individual variability that real soldiers might exhibit. Because the model has been highly specified it may be represented as a structural equation model (SEM). Then the SEM can be evaluated using data from real CEs participating in a real or simulated training exercise to determine how well the data fit the model using several goodness of fit indices. It would be no small feat, though, to obtain the data for each of the measures required by the model. If the model provides a good fit to the data, then it is good enough. If it does not, the SEM can be respecified until a good fit is obtained. SEM is an excellent technique for determining if real data fit a proposed model, but it requires lots of data (data from 200 to 300 participants depending on the complexity of the selected SEM). A real CE who is involved in an exercise in which the opposing forces are controlled by the HPM model may be unaware that his opponent is computer generated force rather than a real opponent. To the extent that real CE's cannot distinguish their opponents as CGF, then the model may be good enough, at least for training purposes. Another metric that may be used to establish that the model is good enough is whether the model is capable of generating the range of behaviors that may be exhibited by real CEs in a similar situation. If the model generates the full range of behaviors as the model parameters are systematically varied, then the model may be

adequate for training purposes, even if the hypothesized relationships among individual model components are not completely correct.

Adaptability and Learning Not Included

In the model, the decision to follow a course of action at a particular juncture in the scenario is irrevocable. When the CE makes a decision to commit to a course of action, it is carried through. Hence the CE cannot benefit from realizing his errors within a scenario. Neither does the model allow the CE to learn from mistakes or successes across scenarios. Therefore, the CE's performance does not improve over a series of battlefield scenarios. In the real world, the CE can alter a decision and select another course of action if a decision produces unintended consequences. In the real world the CE can also adapt his behavior to the changing situation and learn from mistakes.

Addressing HPM Deficiencies

Addressing the HPM deficiencies described above is not a trivial undertaking. In many cases, the required data for modeling the effects of human emotions do not exist. The determinants of situational awareness are difficult to identify and are usually specific to a particular situation and combat environment. Likewise CE goals and expectations are difficult to model and comparisons with combat outcomes are problematic. Collecting data on real commander behavior is very time consuming, even assuming that commanders willing to participate can be found. Finally implementing learning routines to modify human performance has not matured to the point where researchers can confidently include learning subroutines in their models. Even developing models that include adaptive behavior is not a trivial problem.

Developing the HPM Expanded Concept

Despite these difficulties, it is imperative that we expand our models to the extent possible. With this goal in mind, we have developed a concept for expanding our current model to include elements of situational awareness, CE goals and anticipated outcomes, and a larger array of personal traits/characteristics and cognitive/emotional states. Among the personal characteristics being considered for inclusion are Intelligent/Dull, Experienced/Novice, Aggressive/Timid, Risk-taking/Cautious, Extroverted/Introverted, Independent/Cooperative, and Internal/External Locus of Control. Cognitive/Emotional States that may be included are Aware/Confused, Angry/Serene, Alert/Asleep, Rested/Fatigued, Anxious/Calm, Aroused/Subdued, and Fearful/Confident. The personal characteristics and cognitive/emotional states are specified in terms of bipolar opposites, although it is recognized that they will vary along a continuum. The basic structure of the expanded conceptual model is shown in Figure 4. A brief description follows. The expanded model shares many of the personal characteristics and cognitive/emotional states found in the previous model, but may handle some of these variables differently.

HPM Expanded Concept Description

Each block in Figure 4 represents an important human performance variable. Some variables are duplicated to improve figure legibility. The CE's goals and anticipated outcomes are a function of the mission performed and are moderated by the physical resources available for mission accomplishment and other situational constraints such as weather and terrain. Goals and anticipated outcomes also depend on the personal traits of the CE. These personal traits, in turn, influence the CE's cognitive/emotional state. The CE's traits, goals and states determine awareness of, attention to, and interpretation of events occurring in the combat environment. The CE's interpretation of these events in conjunction with time pressure results in an altered cognitive/emotional state. This altered state will interact with current goals and anticipated outcomes to determine the course of action selected and its implementation. The CE then evaluates the outcome based on current goals and anticipated outcomes. The interpretation will change the CE's cognitive/emotional state and preparation for the next event.

Concluding Remarks

Note that the model shown in Figure 4 is conceptual and therefore does not include the detail found in the math model shown in Figures 1-3. However, many of the functions shown in the current math model can be adapted to the conceptual model as it is further developed. A major developmental effort will be needed to determine the form of functions for the model elements that are not included in the current model. ARI is supporting three independent efforts by experts in human performance modeling to incorporate emotions and personality variables into HPM. These efforts may provide functions and techniques for modeling some of the elements not currently represented. Full development of the conceptual model will be contingent on additional funding and continued support for this work.

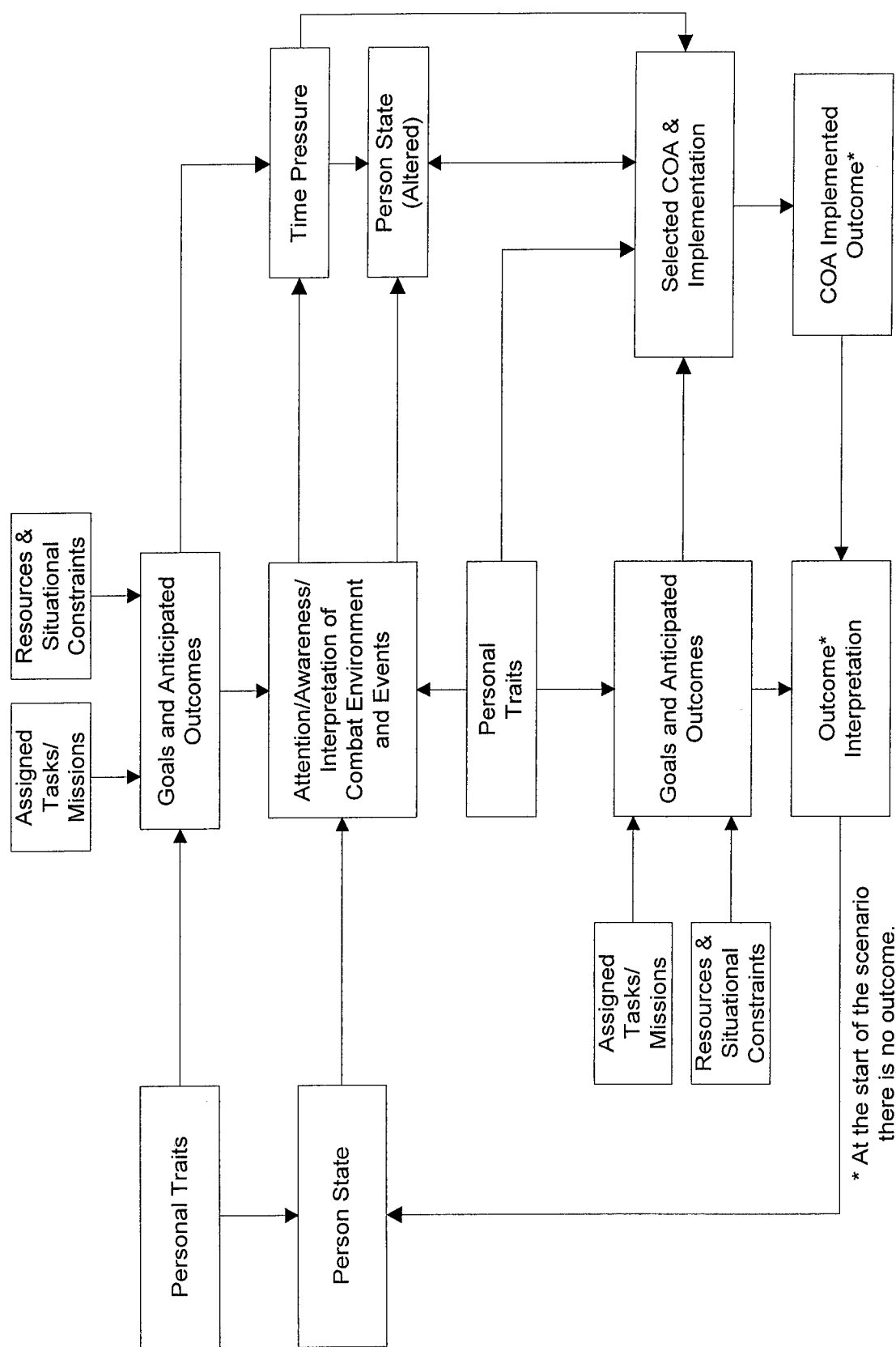


Figure 4. Concept for expanded human performance model.

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