

# DNA-MAN: Dynamic Natural Attributes for Synthetic Military Forces

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***Abstract- Higher-fidelity human behavioral models promise to enhance a wide range of simulations where high-risk and high-threat environments make human performance assessment difficult. This paper explores a methodology for implementing high fidelity human behaviors in simulation. In addition to combat models, first-responder simulations for police, fire, and rescue may benefit. Homeland security simulations ranging from border patrol to civil defense and the Global War on Terrorism are also prime candidates for these techniques.***

## I. INTRODUCTION

Today's Army combat simulations are critical tools for soldier training and system development. These simulations typically create Computer Generated Force (CGF) entities with identical personal attributes, despite the fact that no two real people are exactly the same or behave in the same manner. As a result, they have limited focus on individual human behavioral factors and their impact on the system. The goal of this ongoing research is to develop a highly realistic and quantitative model for human behavior for Army combat simulations.

Extensive work has been conducted in behavioral science to determine what physiological and psychological factors drive human action, but this information is often overlooked in the development of simulations. Instead, there is emphasis on realism in graphics, terrain, and basic combat actions. The integration of human factors will help bridge the gap between actual and synthetic environments and increase the overall fidelity of the host simulation. This research implements insights from clinical studies and behavioral theorists to drive the performance of CGFs. The approach is to integrate a commonly-used personality indicator, the Neuroticism, Extraversion, Openness Personality Inventory Revised (NEO PI-R), with a state-of-the-art Army combat simulation to enhance synthetic human performance with re-engineered DNA – Dynamic Natural Attributes.

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The research strategy is to develop a conceptual and mathematical model for modifying behavioral inputs in a simulation and then test the model in simulation, measuring the effects that the model has on a given scenario. A comparison of the new model to the original will provide insight into the differences occurring in the actions of the CGFs. The research goal is to identify links between certain traits or human factors and the actions of an entity and gather from it possible ways to increase the fidelity and future applications of such research.

## II. METHOD: APPROACH DEFINED

The research approach consisted of seven distinct phases, listed below:

1. Link personality to specific traits
2. Link behavior to personality
3. Develop mapping of personality traits to behavior through development of a model
4. Determine method to impact host simulation
5. Implement modifications into host simulation using the developed model
6. Determine impacts of model on output
7. Analyze and refine model.

## III. PERSONALITY TRAITS TO BEHAVIORS

### A. Big Five Factor Model – Linking personality to traits

The initial phase explored human traits that differentiate one person from another. A widely-used tool to link personality traits to behavior was developed in the 1970s. The Neuroticism-Extraversion-Openness Inventory (NEO-I) was developed by Robert R. McCrae and Paul T. Costa Jr., and was later revised as the NEO Personality Inventory (NEO PI-R). The model claims that in the broadest sense, personality encompasses five major traits, in which several more distinct personality traits could be established. The five broad dimensions of the Big Five personality traits are Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness [3]. These traits have become very well known and applied in business and many aspects of the society, although its validity is often challenged [8].

The *Neuroticism* personality category deals with the tendency that an individual experiences negative emotions, with some relations to impulse control and coping. A low score in Neuroticism usually means the individual is emotionally relaxed and stable with the ability to face upsetting situations without getting upset and disturbed.

*Extraversion* measures how much the individual enjoys being social and being in large groups or gatherings. Some characteristics of an individual with a high score in extraversion are talkative, active, energetic, and excitement seeking. The *Openness* of an individual reveals how curious he or she is about inner and outer worlds, with a tendency to entertain novel and unconventional ideas, experiences, and values. Open individuals experience both positive and negative emotions more intensely than closed individuals. The *Agreeableness* of an individual addresses interpersonal trends. An individual with a low score in Agreeableness will be egocentric, cynical, and skeptical of other people's intentions. The last personality category, *Conscientiousness*, is the individual's ability to resist impulses and temptations. High scores in Conscientiousness suggest a purposeful, determined, punctual, and reliable individual [4]. The Big Five personality categories consist of six facets, shown in Table I, for each domain to provide a more detailed analysis. This model provides one way to link personality to a given set of 30 traits [1].

B. NEO-PI-R – Linking personality to behaviors.

TABLE I  
BIG FIVE TRAITS AND SUB-TRAITS

Neuroticism		Extraversion	
N1	Worry	E1	Warmth
N2	Anger	E2	Gregariousness
N3	Discouragement	E3	Assertiveness
N4	Self-Consciousness	E4	Activity
N5	Impulsiveness	E5	Excitement-Seeking
N6	Vulnerability	E6	Positive Emotions
Openness		Agreeableness	
O1	Fantasy	A1	Trust
O2	Aesthetics	A2	Straightforwardness
O3	Feelings	A3	Altruism
O4	Actions	A4	Compliance
O5	Ideas	A5	Modesty
O6	Values	A6	Tender-Mindedness
Conscientiousness			
C1	Competence		
C2	Order		
C3	Dutifulness		
C4	Achievement-Striving		
C5	Self-Discipline		
C6	Deliberation		

Given these general personality domains and the six facets for each domain, the foundation for the Neuroticism Extraversion, and Openness Personality Inventory (NEO PI) was developed by using a procedure known as factor analysis [5]. These results were refined into developing the current 240 question test revised version known as the NEO PI-R. This test allows us to generate associated behaviors that are supported by the thousands of people who have taken the personality assessment. This test successfully develops one way to link personality to behaviors.

IV. IWARS

The Infantry Warrior Simulation (IWARS) is a constructive, force-on force combat simulation developed by the Natick Soldier RD&E Center (NSRDEC) and the Army Materiel Systems Analysis Activity (AMSAA). It is *constructive* in that the “soldiers,” their weapons and the environment all operate within computer software. It also is an agent-based model used to represent the individual fighter whether as a single entity, team, or a small unit in combat operations [6]. The objective of the simulation is to provide a robust modeling capability needed to conduct integrated, multi-domain analyses that allow the complex relationships between soldiers, their equipment, and the battlefield environment to be explored. Given this analysis the program allows for better decisions to be made in order to avoid unnecessary cost, reduce program risk, and support the development of better equipment [7]. IWARS was selected as the host simulation due to its physiological fidelity and autonomous behavior engine.

V. APPROACH APPLIED: EXPERIMENTATION IN IWARS

A. Mapping personality to behavior

The IWARS architecture was analyzed to determine which aspects of the synthetic soldier could be modified. IWARS entities have 18 common “skills,” listed in Table II, along with descriptions of their functions.

TABLE II  
LIST OF IWARS v.1.0 ENTITY SKILLS

Skill	Description
<i>Change Facing Direction</i>	Change facing direction of entity
<i>Change Field of Regard</i>	Change sensor scanning fan
<i>Change Posture</i>	Change to prone, crouching or standing position
<i>Change Visual Sensor</i>	Change visual sensor used
<i>Communicate</i>	Determines how entity sends/receives messages
<i>Follow in Formation</i>	Gives entity to follow unit leader in given formation
<i>Light Flare</i>	Tells entity to light a flare
<i>Move</i>	Tells the entity to change its current position
<i>Reload</i>	Tells entity to reload its weapon
<i>Remove Message</i>	Command takes away message from entities decision making loop
<i>Seek Cover</i>	Entity goes and seeks suitable cover from fire
<i>Select Weapon</i>	Entity selects an available weapon
<i>Set Formation</i>	Entity in lead sets the formation others will follow
<i>Set Path</i>	Entity in lead sets the path the others will follow
<i>Shoot</i>	Allows entity to engage targets
<i>Throw Grenade</i>	Tells entity to throw a grenade
<i>Wait</i>	Tells entity to not move for a give period of time

Using these tasks as the fundamental skill-set, we broke these skills down into three categories of actions. The categories – the ability to *shoot*, *move*, and *communicate* – are skills fundamental to any combat operation. Table III matches IWARS skills with the basic combat functions.

TABLE III  
BREAKDOWN OF SKILLS INTO CATEGORY

Category	Skill
Shoot	Change Facing Direction
	Change Field Regard
	Wait
	Change Posture
	Change Visual Sensor
	Reload
	Seek Cover
	Select Weapon
Move	Change Facing Direction
	Change Field Regard
	Wait
	Change Posture
	Change Visual Sensor
	Follow in Formation
	Set Formation
	Set Path
Seek Cover	
Communicate	Change Facing Direction
	Change Field Regard
	Wait
	Remove Message

The IWARS skills were further sorted into those that directly and indirectly affect the combat functions of *shoot*, *move*, and *communicate*. The *shoot* function, for example, consists mainly of tasks that affect how often shots can be made and their accuracy. Skills such as *select weapon* and *change field of regard* were considered indirect, supporting skills. Table IV shows the mapping of those skills that directly affect the three basic combat functions.

TABLE IV  
IWARS DIRECT-EFFECT CAPABILITIES

Category	Aspect of IWARS to modify.
Shoot	Reload Time
	Accuracy of Fire
	Acquire Time
Move	Speed
	Direction/Path Take
Communicate	Time to send/receive messages
	Likelihood of entity to send /receive message

### B. Relationships – Determining how traits will impact performance

Causal relationships between traits and actions identify possible effects of modifying a trait and the ensuing actions.

For example, an increase in N1 (worry) would have a positive (+), neutral (0), or negative (-) impact on all of possible capabilities of Table V. We also determined the evaluation measure descriptors such as *more is better* (MIB), *less is better* (LIB), or no change. In the case of reload time, for example, a smaller amount of time used to conduct the task is considered better than a longer time. On the other hand, speed was a characteristic in which more speed brings added value.

Values shown in Table V are based on interviews with subject matter experts at the United States Military Academy at West Point.

TABLE V  
LIST OF IWARS® v.1.0 ENTITY SKILLS

Trait	Reload Time (s)	Speed (m/s)	Time to send receive message (s)	Probability to send and receive message (%)
N1	-	+	-	-
N2	-	+	-	-
N3	-	-	-	-
N4	-	-	0	-
N5	+	+	+	-
N6	-	-	0	-
E1	0	0	0	+
E2	0	0	0	+
E3	+	+	+	+
E4	+	+	0	+
E5	+	+	0	+
E6	0	0	0	+
O1	0	0	0	-
O2	0	0	0	0
O3	-	0	0	-
O4	+	0	0	+
O5	0	0	0	+
O6	0	0	0	-
A1	+	+	+	+
A2	0	0	+	+
A3	+	+	0	+
A4	+	-	+	-
A5	0	0	0	-
A6	0	+	0	-
C1	+	+	+	+
C2	+	0	0	+
C3	+	+	+	+
C4	+	+	0	+
C5	+	+	+	+
C6	+	-	0	+
	LIB	MIB	LIB	MIB

LIB = Less is better MIB = More is better

### C. Extent – Determining what impact traits should have on behavior in simulation.

A spreadsheet model was developed that links each of the Big Five and their sub-traits into an overall personality score based on the NEO PI-R model. For initial model verification, pseudorandom numbers were generated to approximate and individual’s personality profile. These pseudorandom numbers mapped to specific scores on the NEO-PI-R. Mean, minimum and maximum values were determined for each of the factors in Table IV.

Table VI lists the aspects and their respective mean, minimum, and max values that affect the basic combat functions.

TABLE VI  
LIST OF VALUES USED FOR DETERMINING IMPACTS ON PERFORMANCE

Aspect in IWARS	Minimum, Mean, Maximum			
<i>Reload Time (sec)</i>	4	6.75	10	LIB
<i>Speed (m/sec)</i>	1 m/s	4 m/s	7m/s	MIB
<i>Time to send/ receive message (sec)</i>	0.01	1.5	5	LIB
<i>Probability of Send/receive Message</i>	0.1	0.5	1.0	MIB

Each trait was then mapped to a normal curve so that the tails of the distribution would end at the minimum and maximum value for that trait. For example, the mean, minimum and maximum speeds of a computer generated force are 1, 4, and 7 meters per second respectively. If an entity had a N1-Worry score of 75, the speed associated for a score of is 6.02 meters per second. A speed is determined for each of the thirty NEO PI-R traits. To calculate an entity's speed during the simulation, only those traits determined to have a relationship with the associated IWARS *speed* skill will be used to generate the associated overall value. In the case of the LIB factors, the group subtracts one hundred from the NEO PI-R value to determine the corresponding value that particular trait.

#### VI. IMPLEMENTATION: RUN SIMULATION WITH MODIFICATIONS

An evaluation scenario was developed in IWARS that sets two combat forces in conflict in an urban setting. One force is defending a city and has firing positions in buildings and from covered and concealed positions on the street. The attacking force is on foot, approaching in the open. A map-view display of the IWARS scenario is shown in Figure 1.



Figure 1. IWARS scenario map view

The cluster of objects at the top of Figure 1 represents individual soldiers advancing on the city. IWARS also allows analysts to observe individual behaviors in a 3D view. The same scenario, captured from the attackers' point of view, is shown in Figure 2.

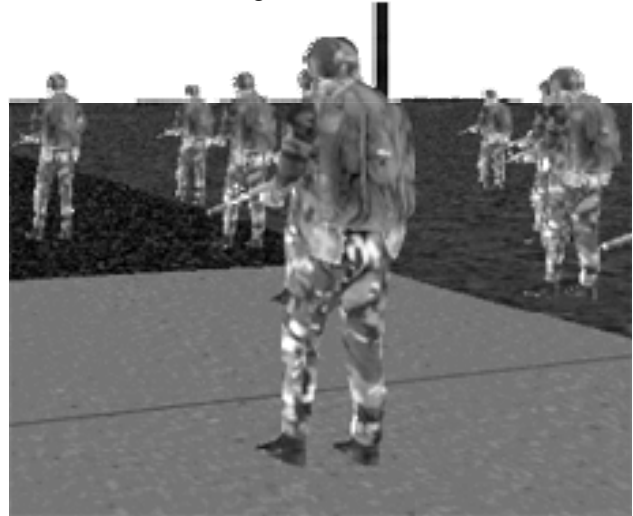


Figure 2. IWARS 3D view

A scheduled validation scenario will apply the DNA modification methodology to a well-documented historical battle. A detailed description of this scenario is described in Section X.

#### VII. APPROACH: COMPARISON OF SCENARIOS

The approach for validating the model is to compare output from a base case scenario with that of the enhanced model. The verification scenario, designed to determine if the model is executing as expected, has been developed.

An initial series of pilot runs was conducted to determine the required number of replications (sample size) for validating the model. Thirty-five pilot runs were conducted to determine the number of runs necessary to capture the true variance of outcomes with 90% confidence, and a desired level of absolute precision of plus or minus one for the survivability (number of blue forces killed), lethality (number of red forces killed), and duration (time until mission was complete) measures of effectiveness (MOE).

The next step is to conduct a fractional factorial experimental design. A factorial design of experiments (DOE) will show main and interaction effects of behavioral factors that influence the outcome of the simulation. A fractional factorial DOE will reduce the number of design points required with a predictable loss of precision.

The experimental design technique will identify which factors, if any, have a significant effect when changed from the baseline to the DNA-enhanced values.

#### VIII. RESULTS AND ANALYSIS

Initial runs of the verification scenario indicate that mechanism exist to implement results from the DNA model

in IWARS. Additionally, IWARS includes a robust data collection and analysis capability which can capture effects of modifying the synthetic entities' DNA. The project has successfully progressed through the seven phases defined in the research approach specified earlier in this paper, although specific results quantifying the outcome of DNA engineering are not yet available.

## IX. CONCLUSIONS AND RECOMMENDATIONS

Initial results suggest that this methodology may prove valuable for analysts and trainers in high-risk conditions such as combat or disaster first-response.

Trade-offs between behavioral fidelity and scenario size were identified as issues. IWARS continuously calculates physiological factors include heart rate and respiration and is limited in the number of entities it can track. The addition of behavioral decisions based on leadership, morale, and personality further stress modern computers' ability to execute simulations in real time. Methods for distributing the computational workload through a grid of computers or through a High Performance Super Computer (HPSC) should be explored for larger-scale scenarios.

Given that we have a possible method to determine particular output in the simulation, we should test this method using stronger and experimentally supported relationships. This will allow for more validity to be given to the impact of the model in the simulation. One way the group plans on achieving this added exploration into the relationships of performance in simulation is to conduct a test to determine if a correlation exists between the NEO PI-R scores of cadets at the United States Military Academy and their performance on an Engagement Skills Trainer (EST). The EST allows cadets and soldiers to conduct marksmanship training. Once the cadet has been trained on the apparatus, the cadet is then put into a computer generated scenario that can track key aspects of the performance of the cadet to include the accuracy of fire, lethality of shots, time to conduct mission, and also time to engage different targets among a host of others. We plan to explore the performance and determine if there is any correlation to the scores on the NEO PI-R. This information will then provide support for more refined relationships in our model.

## X. FUTURE WORK

A validation scenario based on an historical battle is being developed in parallel with the verification scenario. The selected battle is the British coup-de-main against the German-held Pegasus Bridge in the opening minutes of D-Day on June 6, 1944.

In this battle, a small but very highly trained and elite British airborne unit landed in gliders within meters of the bridge across the Caen canal in Normandy. Within minutes they successfully seized and secured the bridge and other key terrain features nearby that had been defended by a

mixture of German soldiers and conscripted eastern Europeans. Many analysts of the battle attribute the success of the small British unit due to the leadership and personality of the soldiers and a corresponding lack of the same by the defenders. Comparisons of the DNA-enhanced synthetic soldiers with actual events and timelines that occurred are expected to provide valuable insights into the validity of the model and the methodology.

Given a validated model, the group believes that the traits that have the most significant impacts can be focused on for future training of soldiers. If certain traits are identified as significant to the outcome of victory, training and improving these traits or increasing the self awareness about common tendencies may increase the soldier's ability to perform his or her mission. This mission can be in all types of professions that are critical to saving lives such as paramedics, police, and fire department forces and those individuals who are mission essential to crisis and disaster response.

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