Toward A Human Behavior Models Anthology for Synthetic Agent Development

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March 2001

ABSTRACT

This paper describes an effort to foster the availability of Human Behavior Models / Performance Moderator Functions (HBM/PMFs) that the modeling and simulation community can use to increase the realism of their human behavior models. HBM/PMFs quantify the impact of human performance to internal and external stressors, and help to capture the role of personality and individual differences. To facilitate that process, we are creating a web-based anthology of HBM/PMFs that abstracts many 100s of them from diverse literatures, maps them into a taxonomy and common mathematical framework suitable for implementation, and assesses their validity and reuse issues. This paper reports on progress to date, anthology construction issues, and lessons learned.

1) Introduction and Summary

The purpose of this effort is to create a capability that will help simulation developers link simulation user requirements to the appropriate methods/techniques to represent human behavior and cognition in the simulation being developed. In the past these representations have often been unrealistic and/or inappropriate for the intended use of the simulation. The cognitive science and psychological literature, as well as other sources, contain a myriad of potentially usable representation methods/techniques, many of which have some degree of validity and utility. Simulation developers must determine which of the literature is relevant and which of the methods/techniques are best for their simulation.

Some of the literature contains descriptions of experiments with strong supporting data, some of the literature provides well formulated human performance models/performance moderator functions (HBM/PMFs), while other segments of the literature contain hypothesized techniques, with only anecdotal support. In most cases, given sufficient time and knowledge, it is possible to develop, with varying degrees of validity, performance moderator functions that can be used to represent the behavior or cognition that is needed in a simulation. Unfortunately, simulation developers lack both the time and proper skills to identify which methods/techniques are most appropriate for their simulation or to make the transition from the more general descriptions or experimental results to the more specific HBM/PMFs.

1.1) Research Goals and Objectives

One of the leaders in trying to improve the realism of synthetic personas is the US Pentagon's Defense Modeling and Simulation Office (DMSO). They are interested in increasing the fidelity of training simulators by populating them with computer generated forces that are highly realistic. Specifically, the DMSO Modeling and Simulation Master Plan calls for the development of authoritative representations of the typical behaviors of combatants and crews/teams engaged in hostilities as well as operations other than war [1].

Our goal is to provide the expertise needed to develop HBM/PMFs from the more general literature, identify the utility of individual HBM/PMFs for varying user requirements and to provide an effective and efficient way for simulation developers to transition from user requirements to usable HBM/PMFs.

To better appreciate what is involved it is essential to understand more about HBM/PMFs and the basic approach that will be taken to provide this new capability. A HBM/PMF captures a dose-response type of relationship between a performance moderator and the level of performance. These moderators reflect significant dimensions of individual and group differences (e.g., intelligence, skill, judgment, leadership, emotion, organizational culture, motivation, dedication, slips/lapses/biases) as well as external stressors on individuals and/or groups (e.g., task time, noise, fatigue, stress, opponent actions, etc.). The modeling and simulator communities are finding it difficult to extract performance moderator functions from the behavioral literature. Our goal is to reduce this difficulty by removing the cross-community barriers shown on the right of Figure 1 and to turn their respective assets into a set of sharable resources for the modeling and simulation community as Figure 1 tries to portray. We discuss this Figure below in terms of three guiding principles:

1.1.1) **Create an Evidence-Based Anthology** – In the field of medicine, a vast amount of data, result sets, and lessons learned are being generated by all the clinical trials that are revolutionizing practice. Since each trial has both strengths and design flaws, an international effort has been launched, largely volunteer, to share the result sets (underlying data, study design, and conclusions reached) in evidence based repositories that include a "structured abstract" for each study [38]. This structured abstract is written by qualified reviewers who attempt to extract the study highlights and guidance, and to provide a validity assessment of the utility and applicability of the results. The utility of the structured abstract has caught on in medicine, and many volunteer reading groups and journal clubs have formed that now routinely author such abstracts.. As Figure 2 shows, our effort is an attempt to launch a similar evidence-based anthology approach for capturing the HBM/PMFs from behavioral studies, experiments that derived them, and raw results from these studies and from CALL centers and other sources of observational data sets. Later in this article we explain the structured abstract, the validity rating scheme, and related paraphernalia..

1.2.2**) Adopt a Common Representation Framework** -- In keeping with the cross-community approach, we have adopted an implementation-neutral mathematics for capturing, representing, and sharing all HBM/PMFs and behavioral architectures (see Section 2). While each modeling and simulation group tends to program behavior within their own implementation framework, having a common mathematical representation should permit the interpretation and integration of HBM/PMFs implemented by diverse programmers.

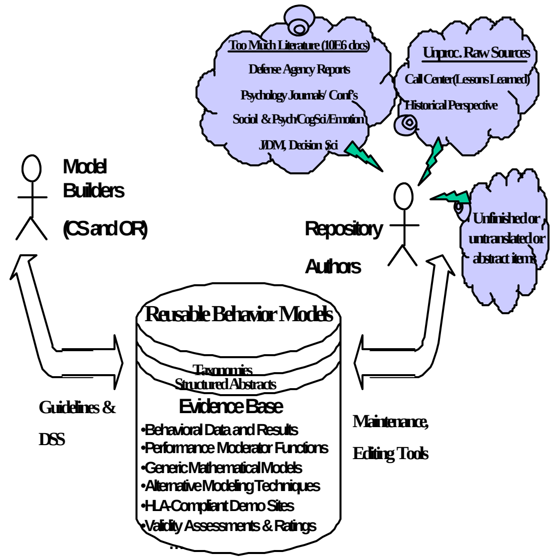


Figure 1 – Human Behavior Model Anthology (HBMA) can Foster Use of Performance Moderator Functions

1.1.3) **Assure the High Level Architecture (HLA) Approach** – At the implementation level, the modeling and simulation community is interested in pursuing a standards-based approach that leads to integration and inter-operation of diverse models and simulators. No one has the resources to mine all the behavioral literature and capture what's relevant in a modelers' anthology; assess the validity of that knowledge and map it into performance moderator functions; test out these functions in combatant simulation tools in order to assure the functions are generic and rapidly deployable; and produce and maintain implemented code. What is needed instead is a sharable library We view the SAF environments as an HLA-compliant repository for reusable HBM/PMFs in the computer generated forces domain..

2) Conceptual Modeling Framework (CMF)

Central to our effort to develop an anthology of reusable HBM artifacts is a valid framework around which to organize the literature and models. We call this the Conceptual Modeling Framework or CMF. Validity here means the framework addresses common problems in taxonomy and framework development as identified by numerous researchers including semantics, level of detail, conceptual basis, and measurability [3-8]. In terms of semantics, the difficulty tends to be the meaning of terms used. To reduce this difficulty, we attempt to tie most terms to de facto standards such as military handbooks and glossaries. Further, wherever possible one wants to adopt the definition of terms utilized by seminal works in a field. The authoritative and most widely available work to date in this field is the National Academy Press' report by Pew & Mavor [2]. Wherever possible, we have tried to follow terminology and taxonomic categories from their text. A few examples are "internal and external moderators", "performance moderators", "performance moderator functions (HBM/PMFs)", and so on. As our anthology expands, we suspect we will rapidly exceed terminology used in that text. Here efforts will be made to adopt standard military terminologies -- those with clear, understandable, non-ambiguous, approved, and available definitions.

Another concern with taxonomic frameworks concerns their level of detail, and the tying of their details to specific implementations. This may help in local sites where the framework describes a deployed application, but it hinders transferability. Plus it prevents mapping such frameworks to a general theory of HBM. There are many organizing frameworks in the literature, and there are several quite useful taxonomies of the taxonomies that are surveys or meta-analyses of the existing frameworks [e.g., see 5-7]. In trying to follow the lessons of these meta-analyses, we have kept our framework succinct and clear. At this juncture we see no reason to add long lists of moderators, performance moderator functions, MOEs, and other elements. While the other taxonomies provide nearly endless lists of such artifacts (with far too few definitions), this is misleading as there is little rigor behind the artifacts. Our criterion for adding artifacts to our listings is that they have mathematical grounding and measurement rigor, two points we discuss in tandem with the last two concerns.

The third concern with frameworks, the conceptual basis, is that a framework be explicit, and structurally coherent. The framework we propose is based on parametrics and is grounded in a common mathematics based on game-theoretic decision science, stochastic modeling, and Bayesian probability. This way we avoid abstract notions, a labyrinth of intricacies in cognitive architecture, subjective views of psychology, and controversies over internal workings of the mind.

Lastly, we are concerned that our conceptual modeling framework or CMF satisfy the criterion of measurability. Fineburg [6] points out that measurability becomes an issue when a framework is used outside the system for which it was intended. Since our framework is intended for use by all system builders, we hope to pay particular attention to having measurable descriptors and to providing informative material on their derivation, range of utility, and implementation lessons and suggestions. In fact, artifacts will only be added to our anthology after they pass the test of measurability.

The conceptual modeling framework (CMF) we postulate to satisfy these concerns is presented in Figure 2. Figure 2 is an attempt to show the highest level of this behavior. Here, we attempt to analogize to how humans receive stimuli, x, from the environment, formulate responses, y, and adapt depending on the feedback. Ignoring for the moment what happens inside a generic agent, its responses might be to take actions itself (aim, shoot, move, operate device, etc.), to direct subordinates' actions, or to coordinate with collaborators. For the time being, we assume inputs and outputs are vectors of attribute-quantity or attribute-value pairs (or reducible to such, perhaps with uncertainty qualifiers) such as force size, armature levels, position, direction, speed, and so on for observations and such as movement, aiming, firing, stationing, resupplying, etc. requests and instructions for guidance and orders. It is legitimate for a pair to be a known (attribute):unknown (quantitity), however, an unknown:unknown pair would not appear in the vector although it may legitimately exist in the environment.

The agent has goals, desires, and plans (x', u, and I) and faces an opponent trying to counteract its goals and plans. As it is in a continuous feedback loop, it is interested in repetitions of the cycle to carry out plan intentions (I) and satisfy goal sets, x' and u. In general, the x and y are viewable as signals -- neuromotor signals when controlling and observing the impact of the agent's own actions, and textual or audiovisual signals when trying to influence the behavior of subordinates or collaborators. Such an agent might be in a multi-tiered hierarchy with superiors above it and subordinates to control beneath, or it might be in a crew with collaborator agents with whom it seeks to coordinate actions.

The details of specialist agents mental processes will of course differ depending on whether they are commanding other troops for a several day period, coordinating their actions over a short interval as part of a crew, aiming their own gun in real time, and so on. Still, at the highest level, we think the same set of internal processes can be used to discuss the functioning of any agent in the hierarchy, in a crew, or even of any adversary. The internals of a generic agent's reasoning processes, are also analogous to a human neuromotor process. As Figure 2 also reveals, they include steps to:

1) **acquire (A)** data and cues from the external world (x, x'), based on their prior focus of attention (f), and level of arousal or valence (v), and filter out noise to produce a set of state variables (s), as output.

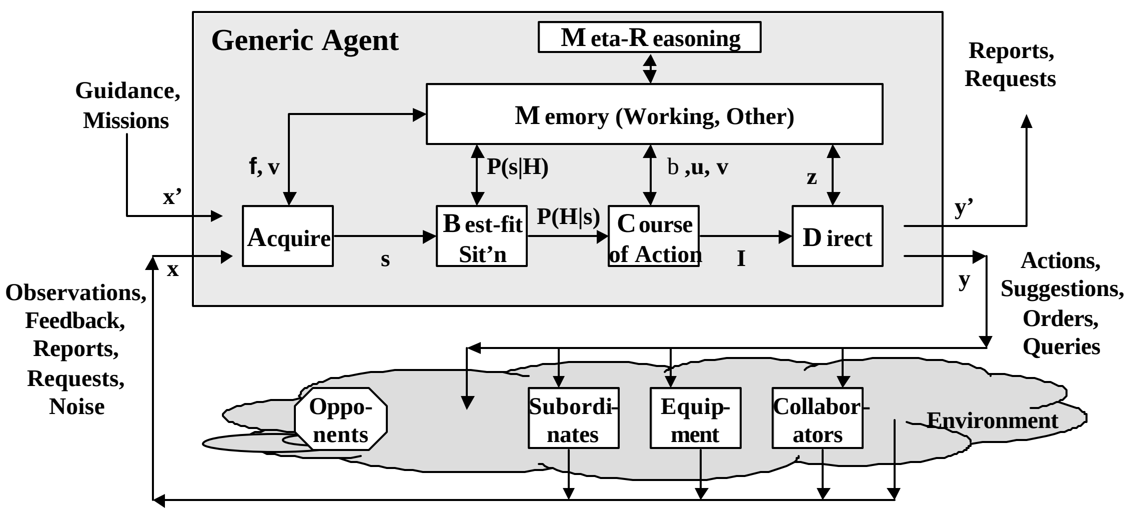
2) **best-fit (B)** what situation they're in based on the cues they attend to (s), and the patterns they recognize from experience, doctrine and value sets, P(s|H). This will lead them to several situational hypotheses (H), being plausible, and a likelihood value being assigned to each, p(H|s).

3) **choose (C)** what course of action to pursue by selecting a decision rule (based on doctrine and on the time they have to plan and decide), utility or desire levels (u), emotional intensity levels (v), and belief sets (β), about the effectivity of their actions over time and space and against the opponent. The output of this step is an intended plan, or an intent (I).

4) **direct (D)** the individual steps, Z, needed to carry out the plan and achieve the intention. This step begins with an effort to identify the actions needed to carry out the plan, and ends by converting them into output signals, y or y', in the agent's effort to optimally control its portion of the external world including its own behavior as well as that of others it might be able to influence.

It is important to note that the Generic Agent of Figure 2 has a memory component (M). This keeps it from being a purely reactive entity. The memory gives it the doctrines, decision rules, belief sets, recallable patterns, desires/utility levels, and affect arousals to help it act proactively and in a goal-directed manner if time allows. We divide memory into working memory (a blackboard space for interacting between other steps) and all "other" memory.

The reader has probably noticed that the basic sequence of steps in this cognitive architecture is labeled **ABCD**. This is just a mechanism to facilitate labeling in the repository. One can almost directly map this scheme to that of many other cognitive theories. For example, Wohl [10] uses what he refers to as the SHOR paradigm, standing for stimuli, hypothesis, options, and response. Likewise, the US Army calls these four steps acquire, assess, determine, and direct [11], Boyd [12] calls them the observe, orient, decide, and act (OODA) loop structure, and Orr [13] maps those into the



LEGEND

x = vector of input data (x' is from superiors)	β = belief set (rules, cases, foe behavior, etc)
f= focusof attention , v= valence or intensity	u = desires or utilities of various outcomes
s = vector of state variables (cues attended to)	I = intentions or plans to carry out in the environment
P(s|H) = probability of those states given various situations (H)	z = actions, plan parts
P(H|s) = probability of a situational hypothesis (H) being true	y = vector of outputs to effect the world (y' to effect superiors)

Figure 2 – Blowup of the Internal Mental Processing Components and Interfaces of a Generic Agent Interacting With Other Agents in a Multi-Tiered Hierarchy and in a Continuous Feedback Loop to Carry Out Goals in the Presence of Opponents

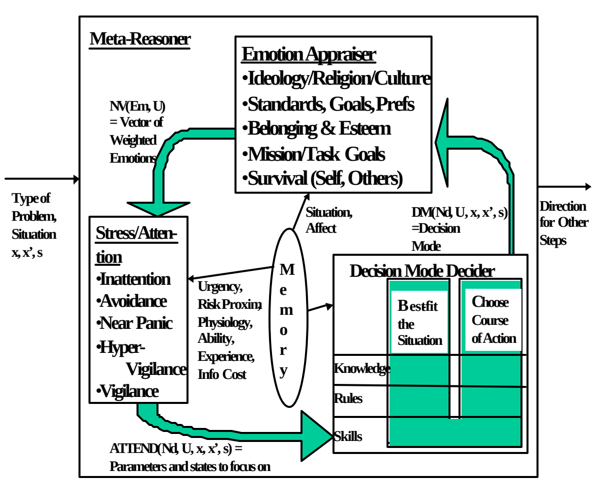
conceptual combat operations process. Simon and Newell [14] ignore steps A and D, call step B "intelligence," and breakout step C into "design and choice". They do, however, devote attention to the meta-reasoning aspect of each step. A useful comparison of 60 such models may be found in Crumley & Sherman [15].

One of the goals of the human behavior modeling repository (HBMR) is to catalog empirical measurements of parameters that describe behavior of the generic agent. For example, two such parameters are Reaction Time (RT) and error rate (ε). When no subscript is used, these are the RT and e of the entire Generic Agent. The ABCD may be used as subscripts to denote the parameter value for one step of the cognitive process. For example, RT_A or ε_B. There will also be a reserved subscript of M for memory processes. One can reasonably combine lower level parameter values to compute higher level ones, such as $RT = RT_A + RT_B + RT_C + RT_D + RT_M$ if we assume that meta-reasoning RT is absorbed in those other components. A linear additive model may not strictly apply to every aggregator, for example overall error rate might be a multiplicative form. At any rate, this use of ABCD and M as reserved subscripts gives the repository a simple to remember notation scheme.

2) Meta-Resoning

We also need to mention the meta-reasoning process that determines largely how all other blocks will perform. Figure 3 depicts the meta-reasoning process as consisting of a need selector, an attention focuser, and a decision rule decider as we will now briefly elaborate.

Figure 3 – Meta-Reasoning Layer of the Generic Agent in the CMF



Our discussion of meta-reasoning starts with the "emotion appraiser" which provides a cognitive appraisal function whereby the situation is played against the ontology of needs and that generates emotion activation/decay, current need utilities, and affect impacts. In terms of the need ontology, it is guided somewhat by the Maslow Need Hierarchy [16] as an organizing paradigm, though we reject his concept of seriality of needs. Maslow's research reveals 5 levels of human needs starting with the basic survival, and progressing through keeping the job (mission, task), feeling of belonging (loyalty and followership), gaining esteem (rank, promotion), and intellectual fulfillment. These are just a start at organizing the full ontology of needs, standards, preferences, and goals that ultimately are required to model diverse agents and their emotions. There is a small but growing literature on the types of parameters that each emotion may force into focus: e.g., see [17]. Ortony et al. [18] provide a useful taxonomy of what emotions activate/decay in response to events, objects, and other agents' actions. Other authors provide preliminary estimates of emotional activation/decay rate functions (e.g., see [19]). Our other papers in this conference provide a closer look at how this works: [17, 20].

Once the vector of emotions and the need utility multipliers (U) are set, the stress/attention focuser is triggered (left side of Figure 2). One rarely drops into a situation with no prior experience, memory or beliefs about it. In addition to need levels, prior memory of the situation at both the previous time interval (t-1) and from long term recollection combine to color those aspects of the input stream and state parameters that will draw the attention of the agent. In addition, the agent's current abilities, physical status (healthy, fatigued, injured) as well as current emotional mood (e.g., calm, frightened, anxious, paranoid, etc.) will further alter the breadth and depth of parameters that the agent can process.

Janis and Mann [21] in turn, show how much of this combines with overall affect (can I be successful?) and situational parameters such as time urgency, cost of information, proximity of hazards, etc. into an algorithm for determining six stress levels and for whether to cope effectively or not. Grossly ineffective coping behavior appears as outcomes such as unconflicted adherence, defensive avoidance, and/or hyper-vigilance (panic). The alternative is opting to be vigilant and to proceed more rationally.

If the option is to proceed more rationally, then the final step in meta-reasoning is to decide how to decide, or to select the path to best-fitting the situation and choosing the course of action. The seminal work on this topic is Rasmussen [22] who breaks out situation assessment and decision processing into three modes – skill, rule, and knowledge. Skill situations are near-automatic and largely unconscious, with almost a Gestalt-like response to stimuli. An example is continually estimating the position of, aiming on a predictive trajectory toward, and shooting a gun at a moving target in one's field of view. There is a substantive literature on the mathematical modeling and simulation of this "automatic" behavior or skill mode via the signal detection and control paradigm: e.g., see [23]. By contrast, assessments and choices made in the rule mode are governed by procedures, doctrines, or experiential cases and rules. This mode requires the agent to select and recursively process a rule set or a case base both for the situation estimation and for the course of action planning. Klein [24]'s model of recognition primed decisionmaking is one of the models of how this mode works, though the Janis and Mann model mentioned earlier also partially falls under this mode. Finally, when the agent encounters complexity and has incomplete rulesets it is necessary to graduate to the knowledge mode, provided there is time to do so. In this final mode, the rational agent attempts to utilize more formal models of reasoning such as Bayesian forecasting, decision making under risk or uncertainty and objective vs. subjective probabilistic reasoning. In these cases there may also need to be a secondary decision rule selector process to determine the criteria for decision selection (e.g., minimax, maximin, avoidance of regret, etc.). The output of this step should be the choice of decision mode to use, not the actual best situational fit or course of action. If there is a mismatch between the decision making mode dictated by the situation and what is available (due to lack of training or readiness), this could alter the need set, and the attention focus. For example, if the agent were missing the skills needed to drive a certain vehicle, the need to flee (and survive) might be thwarted and this could lead to heightened anxiety or panic.

3) Derivation and Validity of HBM/PMFs

As already stated, a primary goal of the HBMA is to supply the moderators and HBM/PMFs that can be utilized by those trying to improve the realism of human behavior in models and simulations (ie, to implement the conceptual framework for given scenarios). Without these reusable artifacts, the conceptual model will be little more than a theoretical construct at best. In an effort to begin populating the HBMA with these artifacts, we are transcribing HBM knowledge into a set of "structured abstracts" of the literature (and raw data sources).

Figure 4a shows the template of a structured abstract contains several sections. The top of the template includes the Reference Section, which is largely useful for indexing and searching purposes. Likewise the Task Section serves a vital role in helping to organize the abstract within various taxonomic categories that will be useful for users trying to browse and search the web anthology. The lower half of the template in Figure 4a, however, turns to the issues of evaluation. These sections are designed to help a reader to quickly determine not only the study's HBM/PMFs in the Findings Section, but also the study's design strengths and weaknesses can be assessed in the Methodology Section. This tells the reader how the HBM/PMFs were derived, what types of subjects were used in the study, and what conditions were evaluated. Continuing in this vein, the Findings Section includes a field on the validity (discussed in the next paragraph) and on the lessons learned from this study. Lastly, the template includes the study's original abstract, and a section on CMF which includes a mapping of the HBM/PMFs of the study into a common mathematical framework discussed in Section 4 of this paper.

To assess validity for HBM/PMF construction, we have adopted a 5 point rating scale ranging from 5 for VERY HIGH validity to 1 for VERY LOW and with a sixth category or a zero score reserved for irrelevant. As Figure 4b shows, a study's validity increases to the extent it is grounded in empirical data (and not just theoretical) and to the extent that it contains HBM/PMFs that are ready to be utilized by the modeling and simulation community.

It is a commonly encountered belief that there is little in the literature in the way of results that are of direct value for extracting Performance Moderator Functions (HBM/PMFs) to be used in Human Behavior Models (HBMs) the HBM Anthology (HBMA). Pew and Mavor (p.242) call these the "individual difference variables about which the least is known so that they cannot at this point be encoded directly into a model." To test out the extent to which this seems likely to be a significant barrier, we prepared abstracts on ___ studies covering PMFs.

As Figure 4c shows, part of the negative prediction is born out – only 4% of the studies are in the VERY HIGH category, those offering empirically grounded HBM/PMFs directly available for use with no further manipulation. However, about 39% of the studies appear well-grounded in terms of study design and data availability and offer immediately useful data for constructing HBM/PMFs. The even more encouraging finding is that another 41% (Mediums) could be turned into working draft HBM/PMFs although they have to be properly labeled ("use with a large grain of salt") and eventually should be replaced. Also, 14% of the reports pose interesting theoretical frameworks of value to human behavior modeling, although there is no empirical data behind these. Some of these studies (e.g. OCC) are more influential in the modeling and simulation community than the medium and high validity ones, so one cannot entirely discount such literature and it is worth writing up abstracts on at least some of it. Finally, only 2% of the studies (Very Low and None) appear entirely useless.

It is also interesting to note that thus far, we are averaging about 8 HBM/PMFs per literature item, a rate we expect will hold up as literature we have yet to examine seems at least as rich in HBM/PMF material. Also, about 2/3rds of the HBM/PMFs fall into the ABCD or reasoning layers of our CMF, while the other third thus far concern the meta-reasoning layers.

4) Concluding Remarks and Next Steps

Increasing the realism of virtual characters is an important objective if we are to have useful training simulators, mission rehearsal environments, and discovery and learning aids. The human behavior literature is filled with material that can be mined to ground realism-enhancement efforts in actual empirical results. The problem is that this literature is highly incomplete, and non-structured relative to agent coding needs.

The effort described here is an attempt to create a reusable artifact anthology for human behavior modelers, an HBMA. This HBMA is particularly focused on artifacts that can enhance realism of virtual characters, and not on

FIGURE 4 – The Structured Abstract Is The Primary Artifact in the HBMA

(a) Structured Abstract Template

- **Title:**
- **Authors:**
- **Organization:**
- **Reference Number:** **Date:** **Pages:**

– **TASK**
- **Domain:**
- **Echelon:**
- **Tasks Studied:**
- **Cognitive Framework:**

– **METHODOLOGY**
- **Study Goal:**
- **Study Procedure:**
- **Number of Subjects:**
- **Arms of Study:**

– **FINDINGS**
- **Human Behavior Models:**
- **Performance Moderator Functions (PMF):**
- **Modeling Technique:**
- **Lessons Learned:**
- **PMF Validity Info:**

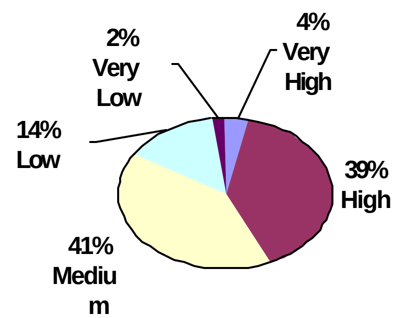
ORIGINAL ABSTRACT

CONCEPTUAL MODEL FRAMEWORK (CMF)

(b) Validity Assessment Scale

Scale:	Degree of Value of Literature Item for Constructing PMFs
5= VERY HIGH	PMFs provided with backup data sets
4= HIGH	Could make PMFs directly from the data in this study
3= MEDIUM	Some preliminary data for initial PMF construction, but more data needed
2= LOW	Theoretical model suggested from which an ungrounded PMF could be derived.
1= VERY LOW	No valid data in this report for PMF construction
0= NONE	Irrelevant to the PMF construction process.

(c) Percent of Human Behavior Literature in Each Validity Category (based on a sample of 486 HBM/PMFs in the Anthology)



providing virtual characters themselves. It is our belief that the human behavior literature is too diffuse and jargon-filled for the typical military modeler. To help them use and reuse human behavior models, it is vital to provide a Human Behavior Modeling Anthology (HBMA) that will help modelers find HBM/PMFs, and will also help them develop their model construction requirements. The HBMA will be most usable if its organized around a taxonomy and metaphor that's intuitive to agent builders and military modelers, and if it maps the HBM/PMFs into a common mathematical framework.

In order to foster the understanding and reuse of the HBM/PMFs, the HBMA is being designed with several features explained in this paper, including:

- A modern day HBMA website including visual metaphors, online searching and wizard-based model builder support, and FAQ and related help.
- A conceptual modeling framework (CMF) intended to stabilize the semantics, conceptual basis, measurability, and level of detail of the HBM/PMFs.
- A structured abstract intended to summarize the literature and derivational roots of the HBM/PMFs, to provide validation information, to summarize testbed results on HBM/PMF sensitivities and combinatorics, and to convey the lessons and guidance from virtual agent demonstration testbed.
- An assessment of the validity of the HBM/PMFs based on how they were derived and to what extent they are grounded empirically.

This paper presents results of preliminary analysis of the literature. The results of this survey show that there is a significant amount of valuable HBM/PMF material in the literature – over 40% of the studies had HBM/PMFs of high or very high validity levels, and another 40% were medium validity. These are the levels of validity at which one can utilize the results with some degree of confidence. Significant work has been needed to dig the HBM/PMFs out of this literature and make it presentable for reuse in the modeling and simulation community and some manpower estimates were provided.

Also, the good news that the literature holds a reasonable fraction of HBM/PMFs should be tempered by several real-world concerns. For one thing the most heavily populated portions of the literature are the physiological areas that help to determine things like reaction time and error rate as a function of stress level in traditional military tasks. To date, individuals have been studied more thoroughly than groups, and organizations are the least well-studied. The less-studied areas also appear to include the emotive as well as the newer military tasks (e.g., the asymmetric forces problem), though researchers are turning to these topics in increasing numbers. The end result is that there is a significant amount of HBM/PMF material that can and should be mined and placed into the HBMA. However, for any given modeling and simulation development that one wishes to attempt, there will be gaps in what can be reasonably accurately modeled with known, valid HBM/PMFs vs. what is still under investigation and development. Many modeling and simulation developments will need to accept a mix of validity levels in the HBM/PMFs they ultimately adopt. Over time, as the anthology grows and sharing increases, this will become less of a problem particularly for training and analytical applications. However, one should not expect it to disappear where modeling and simulation is done to learn about the unknown.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the financial support of DMSO, in general, and Colonel Forrest Crane, Dr. Ruth Willis, Dr. Phil Barry, and Lt. Col. Eileen Bjorkman, in particular.

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