# Dynamic Representation for Evaluating the Effect of Moderators and Stress on Performance (DREEMS)

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Abstract: Fatigue and other stress factors (stressors) affect Ground Soldier and Small Unit (SSU) operational effectiveness. Analysts require an understanding of the causes and effects of fatigue and supporting data (i.e., to characterize fatigue) and need a way to represent and assess the effects of fatigue on decision-making and physical activities. This paper is about a Dynamic Representation for Evaluating the Effect of Moderators and Stress on Performance (DREEMS). DREEMS is a research program to characterize fatigue and other stressors, define the elements of operational effectiveness in terms of critical tasks and processes, and develop a methodology for finding, analyzing, and using data to characterize the effects of fatigue on operational effectiveness. DREEMS provides the knowledge and data to support modeling the degradation in performance of

physical and decision-making tasks in a constructive simulation.

# 1 Introduction

This paper discusses a Small Business Innovative Research (SBIR) effort by a team of analysts, scholars, and software developers put together by Charles River Analytics (CRA), and operating under the direction of the US Army Natick Soldier System Center. The focus of the effort, Dynamic Representation for Evaluating the Effect of Moderators and Stress on Performance (DREEMS), is an exploration of stressors/moderators in the context of the individual dismounted Soldier and Small Unit (SSU). Our approach is developing a threefold toolset to:

- Describe and quantify fatigue and other stressors/moderators,
- Crosswalk those stressors/moderators to their effects on the performance of critical tasks and processes for specific elements of military operations, and
- Develop a methodology for finding, analyzing, and using extant data/literature to characterize such effects on operational effectiveness.

The CRA team is currently in Phase II of this effort, enhancing methodologies conceived in Phase I and developing proof of concept examples for those methodologies.

## 1.1 Background

In the not so distant past modeling, simulation, and analysis (MS&A) for the individual ground soldier concentrated principally on the physics-based aspects of military operations, looking at that soldier as just a “slow, unarmored tank”[1]. In the decade prior to the turn of the century, that view started to change with the concept of the soldier as a system, which has gradually morphed into the more encompassing “warrior system”. In conjunction with that concept, the military analysis community has been working to create models and methodologies that better represent the complexity of human performance in the context of the dynamics of the battlefield.

Representation of the “human” element requires moving beyond the physics of the battlefield to an understanding of human physiology and psychology. "Good" MS&A of the individual and small unit must consider humans as processors of information that accept inputs (scenarios, environmental conditions, missions, their own state and behaviors) and produce outputs (decisions, actions, mission performance). The digital battlefield and the evolving military mission space have further driven the transition in emphasis from modeling the individual as characterized by actions (move, shoot, communicate) to incorporate the concept of a decision-making entity - one who continually evaluates the battlefield dynamic to decide when, where, and how to move, shoot, and communicate.

Stressor induced performance degradation can result in serious, costly mistakes and slower reaction times, ultimately determining whether the SSU will survive. For example, previous research shows that exhaustion can cause riskier decision-making and loss of psychomotor control [2], two elements essential for operating technical equipment. For the current soldier, the impacts of fatigue and other stressors are further exacerbated by the introduction of information technology and electronic equipment that create cognitively demanding tasks, particularly for Soldiers with limited experience with this new equipment. To provide a basic understanding of the causes and effects of fatigue and supporting data (i.e., to characterize fatigue), analysts must represent and assess the cognitive effects of fatigue on decision-making and physical activities. Understanding and studying the impact of fatigue and other stressors on performance will ultimately enable the US Army to improve SSU survivability and operational effectiveness.

Although there are several tools, architectures, and models of stress currently available, none of them provide the required understanding of the multiple types of stressors and their effects on cognitive and physical performance. There has long been a critical need to define and incorporate representation of performance moderators in operational simulations (see for example, [3-7]). Such models would allow analysts to observe the wide range of fatigue effects and other stress moderators that degrade cognitive and physical performance. For example, how does fatigue from carrying a heavy load all day degrade decision-making speed and accuracy during a room clear? Does physical exhaustion reduce situational awareness for threat assessment? How do multiple fatigue effects combine? A key reason none of the current approaches are satisfactory is because it is difficult to characterize the physiological and cognitive behaviors of the complex human system [8].

### 1.2 Key Concepts and Definitions

A large part of the rationale behind DREEMS is the need to ensure that practitioners from different disciplines adopt common definitions for technical terms. Accordingly, we begin with some key concepts and their definitions.

From the American Psychological Association (APA) Dictionary of Psychology:

- Stress - The pattern of specific and nonspecific responses an organism makes to stimulus events that disturb its equilibrium and tax or exceed its ability to cope.
- Stress moderator variables - Variables that change the impact of a stressor on a given type of stress reaction.
- Stressor - An internal or external event or stimulus that induces stress. [9]

A *moderator* is any factor that affects performance, either by causing or alleviating the SSU psycho-physiological capabilities or by affecting performance directly. *Stressors* can be defined as a type of moderator since stressors can directly affect the quality, speed, and accuracy of performance. Fatigue from carrying heavy loads, heat exhaustion, and sleep deprivation, as well as distractions from technical devices and task overload are just a few of the stressors that degrade a SSU's decision-making and physical performance.

In order to address the issues associated with the DREEMS toolset, we follow the dictum of William Thomsen, Lord Kelvin:

> *"When you can measure what you are speaking about, when you can express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind . . . scarcely advanced to the stage of science."*

We further see the need to recognize a difference between measuring performance and effectiveness; we have adapted definitions from the US Army DoD:

- Measure of Effectiveness (MOE): A quantitative or qualitative expression that compares the effectiveness of alternatives in meeting an operational objective or requirement under specified conditions.
- Measure of Performance (MOP): A measure of how the system elements perform their functions in a given environment. It quantifies attributes of system component behaviors that contribute to overall system effectiveness as described by an MOE. MOPs relate to specific performance characteristics from which data can actually be collected. (e.g., number of targets detected, reaction time, number of targets nominated, susceptibility of deception, task completion time). [10]

These measures are generally applied in a hierarchical structure of assessment tools [11], preferably beginning with measurement of contributing data elements in a laboratory or field setting. These data are used in an engineering level assessment of individual skills or capabilities, which then contribute to assessments of individual performance at the level of Soldier or small unit behaviors, progressing if necessary to force-on-force encounters, evaluating mission or battle outcomes, and on to theater level concerns as appropriate. MOEs are most generally used to assess the result of small unit operations, typically involving force-on-force encounters at the fire team, squad, and/or platoon level, and provide the greatest insight into the operational effects of performance moderators.

We shall interpret the term MOP to the output of data reduction as applied to the results of experiments or field tests. For example, a field test may produce start and stop times for an individual corresponding to distance covered while affected by different levels of a stressor/moderator, which translates directly into an MOP: speed. If we can obtain measurements to relate the individual's physiological state to speed and other measures of terrain trafficability, we can construct mathematical models to predict the individual's level of fatigue and percent effectiveness at various mission tasks.

The reliance of MOPs on raw data is critical to their role in the evaluation of SSU operational performance. Analytical evaluation protocols must ultimately specify not only the data elements to be collected (e.g., the start/stop times), but also the conditions under which the collection takes place, the tools with which they are to be collected, and the metrics applied. This may seem obvious, but a perennial problem for SSU analysts is trying to decide how to compare data recorded in furlongs per fortnight, collected, as far as anyone knows, with a sundial and inter-city mileage table, to data in m/sec., collected with a stopwatch and micrometer. Sadly, much of the time, published reports fail to contain key aspects of the data collection protocols and the conditions under which they are applied. Even worse, it is an unfortunate fact that a great deal of potentially valuable field trial data have been lost, simply because lack of pre-planning failed to have a data collector prepared with a list of start/stop cues and a stop watch at the appropriate place and the appropriate time.

Our ontology development is proceeding in concert with evaluation of several hundred published documents containing data and/or models relating to stressor/moderator MOPs. These source documents are used to incrementally build up the terms and relationships contained in the ontologies. Further, by exploring the different types of data, the listed conditions under which the data are collected, and the nature of experimental/analytical protocols used, we are gradually building a rough template of the material most helpful to DREEMS users, a template we hope will help provide general guidance to augment the individual interests of the many diverse communities that operate in the DREEMS problem space.

To proceed from MOPs to operational-level measures of effectiveness we almost always have to resort to simulation, whether done in the field with troops engaged in simulated combat, or in a computer, where mathematical models predict the outcomes of mission tasks. While SSU proponent decision-makers may prefer the results of field trials, economic realities constrain them to fight the majority of their test battles in the computer. Just as it makes no sense to speak of experimental data without reference to the tools and metrics used to collect them, MOEs cannot reasonably be separated from their derivative models and simulations. These M&S tools determine the context, resolution, reliability, and applicability of their associated MOEs.

A critical factor in the use of experimental or field trial data is the extent to which they may be context dependent, how valid they are to the prediction of performance in other environments. The process of reducing raw data and defining resultant MOPs, almost always results in taking the known results and, through interpolation and extrapolation, extending them to such other contexts. A positive benefit of the fact that MOPs are dependent on observed data is that they can be empirically validated. As the assessment process aggregates data into more abstract MOEs, and when it includes predictions of events that cannot be replicated under peacetime constraints (e.g., casualties), it becomes successively more difficult to speak of validation. The analytical community then turns it focus to verification: the process of ensuring that our mathematical models are internally consistent and correctly implemented. To this end, the linking of our DREEMS tool's contents to source documents is critical. Our links provide an audit trail to data and methodologies. In addition, since the extant literature in many cases fails to be complete, or even consistent, we are constructing our tools to highlight data gaps and inconsistencies, leaving it up to end users to decide what best meets their needs.

### 1.3 The Problem Space

Tanks and airplanes don't get hot and tired, they don't make decisions influenced by their psycho-physiological status, and they are not generally subject to wide variations in performance as functions of that status. They are not subject to the host of so-called "soft factors" that have long been recognized as key contributors to battlefield outcomes: morale, training, unit cohesion, national characteristics, and the like [12, 13]. Their performance is not subject to the variety of moderators and stressors that affect SSU operational performance.

DREEMS is an effort to assist MS&A practitioners in capturing the complex interplay of battlefield stressors and other performance moderators, and their effects on military operations. As such, DREEMS needs to address a multi-dimensional problem space that includes characterization of:

- Stress and other performance moderators
  - Environmental factors that induce, exacerbate, or mitigate stress in an individual – a list of factors that contribute to intensity of stress, or to the rate of growth or decay in stress accumulators and/or

stressor intensity;

- Measures of stressor/moderator intensity at a given point in time;
- Measures of the rate of change of stressor/moderator intensity at a given point in time;
- Stress accumulators, measures that correlate to stressor intensity but that also reflect the time history of exposure to that stressor through summation or integration;
- Mental and metabolic elements of stress, i.e., the physical or mental measures that express the changes in the psycho-physiological state of an individual;
- Individual Baseline factors – factors that account for individual variations in performance and the degree to which it is affected by stressors.
- What physical and cognitive capabilities are influenced by these.

- Mission Tasks
  - Task definition, the task goals and the procedures intended to achieve those goals;
  - Decision processes that dictate task flow and the information requirements for those decisions;
  - Measures of Performance (MoPs), metrics that define the rate and quality of task performance;
  - SSU physical and mental capabilities, skills and resources needed to perform the task.
- Soldier state
  - Dynamic psycho-physiological state;
  - Skills and capabilities;
  - Situation Awareness/Situation Understanding.

As a result, the DREEMS problem space encompasses multiple academic and scientific disciplines, from psychology and cognitive science to physiology and physical behavior, from physics and biomechanics to geography and meteorology, from military science to computer science and artificial intelligence.

To explore cause and effect relationships between stressors and cognitive performance requires understanding how the brain and nervous system represent, process, and transform information, considering such cognitive functions as perception, memory, attention, reasoning and inference, decision-making, and emotion.

Additionally, to explore cause and effects relationships between stressors and physical performance requires understanding how the anatomical and biochemical functions of the body produce the individual's autonomic and physical behaviors, considering the roles of the endocrine and nervous systems in controlling functions from respiration, cardiovascular processes, and homeostasis to fine and gross muscular behaviors.

## 2 DREEMS

The DREEMS effort is producing an integrated suite of tools for the MS&A community, with the ultimate goal of facilitating that community in maintaining and enhancing SSU lethality, survivability, and operational effectiveness in the face of battlefield stressors. DREEMS is a vehicle to promote collaboration among the many different research disciplines involved in the problem space discussed in Section 1.3. It is based on a set of ontologies and other tools that provide a shared understanding of elements and relationships of that problem space, and thus foster the common discourse necessary for such collaboration.

DREEMS is all about human performance, but it is not looking to develop new models or simulations of human performance; it is intended to support those who wish to develop such models and simulations, and/or to enhance current ones. It is not a new analytical methodology but will support a wide variety of analyses with respect to SSU issues. It is not a new decision aid, but will provide data supporting cause and effect relationships to suggest course of action alternatives (CoAs) and/or to predict outcomes from select CoAs.

The DREEMS toolset is designed to support a variety of applications that may differ in requirements for focus, fidelity, and resolution. It can support focused research that explores the theoretical underpinnings and functional mechanisms involved in such areas as: moderator effects on human cognition; mechanisms to mitigate or defeat potential sources of stress; cumulative effects of varying intensities of stress; and/or synergistic effects of multiple stressors. Such in-depth studies may well lead to the construction of statistical distributions of effects to support force-on-force models that cannot afford the computational penalties of direct calculation of such effects. Some such distributions/models may characterize the psycho-physiological effects of performance moderators; others may translate those effects into modifications of task-specific performance parameters that define the rate and/or effectiveness of task completion.

The DREEMS toolset is based on an agile, integrative architecture that supports analysis at multiple levels of resolution and from a wide variety of user perspectives; it captures the factors and factor relationships between data and model elements from an inter-disciplinary perspective. Our approach provides an over-arching foundation for such a wide variety of applications and ensures consistency between such applications with respect to definition of behaviors, data structures and formats for performance moderators and effects, and most important of all, the underlying assumptions as to the factors and mechanisms at work.

DREEMS is comprised of three basic tools: the fatigue and stressor ontology, the SSU performance ontology, and a cause and effect methodology. All of these tools are supported by an annotated bibliography of source material for the elements contained therein. That bibliography currently contains 764 references and is expanding in concert with the continual development of our ontologies.

### 2.1 The DREEMS Fatigue and Stressor Ontology

The DREEMS **Fatigue and Stressor Ontology** characterizes types of fatigue and other stressors, how they arise (that is, the sources of fatigue), how they are quantified and measured, and typical effects on performance. Initial development of this ontology was based on a literature review that resulted in well over one hundred sources of fatigue and stressor related material. Fatigue and stressor types were pulled from this literature and used to create the ontology using the Sonnet Ontology Language (SOL), a lightweight ontology language designed for collaboration [14]. SOL allows us to gather, compare, and contrast terms from different disciplines, and thus supports the translation of multiple reasoning and modeling technologies into and out of other formalisms, which is the exact purpose of the fatigue and stressor ontology.

SOL is based on the definition of types, which consist of:

- Type name – name of the type
- Description – a description of the type denoting which entities may be classified as this type
- Super types – types from which this type derives, a type includes all the aspects of its super types
- Attributes – aspects of the type
- Parts – components of the type
- Source – reference material from which the type was derived or the origin of the type definition
- Comments – additional notations.

The type's Attributes provide a virtually unlimited capability to characterize stressor elements and relationships. For example, attributes can simply list specific stressor effects, which are themselves types in the ontology, or describe "is_caused_by","is_affected_by", and "affects_" relationships with other types from the stressor ontology or the SSU ontology. Attributes can employ other ontology types to distinguish multiple views as might be reported by different report sources, for example, definition stressor intensity and effects as a function different operational contexts.

As allude to in Section 1.2, such data/information source context is critical to applying ontology entries to different application domains. As described by [15]:

> *Explicitly capturing the original context provides a means for recognizing and specifying the conditions under which research was conducted, which informs the conditions in which the research finding may be applicable in the future, and suggests whether the model may be useful in cross-cultural applications. Context is captured along various axes, including audience, geographic location, objectives, media types, statistical analysis, and narrative information.*
>
> *Context is essential for making the summary models usable in operational contexts, and operational tools may present the context to operators so they consider whether the model is relevant to their application. ... An operator may use a research-based model's context to*

> *compare the conditions and underlying assumptions between the model's research environment and their own operational environment.*

The type's Source component points researchers to the source material itself, should they wish to examine it in depth, and provides an audit trail for applications using the ontology. In this regard, one use of the Comments component is to mention associations with other data and source materials, which may either support or conflict with the given material. We should note that while peer-reviewed scientific studies may be the preferred source of data and models, we have found that anecdotal data and subject matter expert (SME) opinions can also be valuable (and sometimes the only) sources of data to support understanding and assessment of moderated task performance and operational effectiveness. As a consequence, we have included such sources in the DREEMS ontologies, and, just as with scientific studies, leave it up to the end-user to decide how applicable/useful data from such sources may be. Our responsibility in this regard lies in providing the end user enough information to make such judgments.

SOL representations are model- and system-independent, which means the Fatigue and Stressor Ontology is a model- and system-independent data source. At present our ontology includes over 60 different types of performance moderators that are related to fatigue sources. We initially based the ontology on just over 30 sources, covering a representative set of research sources and research areas. We looked at both traditional academic papers across several disciplines as well as military reports. By documenting this wide variety of performance moderators, we were able to connect chosen moderators to the breakdown of tasks within the SSU Performance Ontology and begin to link the performance effects certain stressors may have on the breakdown of Soldier tasks.

We are now engaged in expanding the breadth of sources to continue growing the ontology.

### 2.2 DREEMS SSU Performance Ontology

The DREEMS **SSU Performance Ontology** characterizes SSU tasks, skills, and cognitive and physical behaviors. This ontology could have been created with SOL or another generic ontology framework; however, we choose to use a tool with built-in representation for annotating and capturing the detailed breakdown of tasks into underlying skills, metrics, physical and cognitive capabilities. This tool, the Methodology for Annotating Skill Trees (MAST) Skill Modeling Framework [16, 17] uses such task breakdown to facilitate measuring performance on those tasks (e.g., breaking down a room-clearing task into the motor skills for entering the room, the perceptual skills for identifying threats, and the decision-making skills for shooting adversaries). MAST can integrate models of domain knowledge, tasks and skills of multiple types (e.g., perceptual, procedural, decision-making), and metrics. MAST supports linking tasks and skills to decision-making models, which can be built in cognitive modeling languages like ACT-R or Soar. MAST also supports identifying critical skills and ensuring performance of those skills can be assessed in a simulation. As part of DREEMS, we will enhance MAST to include representations of fatigue and other stressors and moderators, as well as annotations that link tasks as causes of fatigue and capture relationships between fatigue and other stressors on task performance. We initially constructed a representative set of three MAST task models (basic marching task, room clear, and general process for search and target acquisition) to address critical SSU tasks identified in cooperation with the Sponsor and our team's subject matter experts (SMEs). We are currently augmenting that task set to include military medical procedures and SSU mobility tasks such as movement under fire and move to contact.

### 2.3 Cause and Effect Methodology

Based on construction of the Fatigue and Stressor Ontology and SSU Performance Ontology, we created a **Cause and Effect Methodology** to model the effect of fatigue and other stressors on performance of critical SSU tasks. The Cause and Effect Methodology combines fatigue stressors and performance moderators documented within the Fatigue and Stressor Ontology with specific task breakdowns in the SSU Performance Ontology to represent and assess the cognitive effects of fatigue on decision-making and physiological activities in constructive simulation.

The DREEMS Cause and effect methodology is based on a Cognitive Task Analysis (CTA) Toolkit that uses MAST skill trees and ontologies to link moderators to the tasks that they affect. Tasks are structured by MAST skill trees, which contain annotations about the conditions under which moderators can be expected to influence performance on a task, via ontology source research on how moderators affect the metrics used to measure task performance.

In the CTA toolkit, task performance is measured by MOPs. DREEMS data sources describe moderators of those metrics, for ecologically similar assessments of the task or others that may be similar. The toolkit links the tasks, metrics, moderators, explicit operational definitions of all relevant terms, and citations providing an audit trail of the links and terms. An additional outcome of the CTA and our approach to annotating skill trees is the highlighting of data gaps, tasks for which little valid information is known concerning moderation of task performance.

Our cause and effect methodology is designed to support individual users that need to implement DREEMS data and model elements for specific analytical applications. It follows a three-step process:

- **Filter** – Define the conditional factors relevant to the application - context, tasks/skills, and/or moderators of interest. Then, within the CTA, explore the data sources for reported/proposed relationships and/or cause and effects.
- **Fusion** – Create an implementation independent design specification for the expression of cause and effect between the relevant moderators and their effects on the tasks/skills under study. As appropriate to the application and the available data, the design specification may be expressed in different forms, e.g., algorithms, statistical distributions or if_then_else conditionals.
- **Implementation** – Adapt the implementation specification to the simulation(s) or other analytical tools being employed for the given study. Example specifications:
    - Physical Fatigue;
    - Heat Stress;
    - Sleep Deprivation;
    - OPTEMPO; and
    - Combat Intensity.

## 3 Summary

Stressor induced performance degradation is a critical issue with respect to Soldier survival and operational effectiveness, one that is not yet adequately represented in SSU studies and analyses. The impacts of fatigue and other stressors are exacerbated by the introduction of information technology and electronic equipment that create cognitively demanding tasks, particularly for Soldiers with limited experience with this new equipment. To provide a basic understanding of the causes and effects of fatigue and supporting data (i.e., to characterize fatigue), analysts must represent and assess the cognitive effects of fatigue on decision-making and physical activities. Understanding and studying the impact of fatigue and other stressors on performance will ultimately enable the US Army to improve SSU survivability and operational effectiveness.

The DREEMS effort is aimed at maintaining and enhancing SSU lethality, survivability, and operational effectiveness in the face of such battlefield stressors. To that end we are developing an integrated suite of tools:

- A series of ontologies defining the types, properties, and interdependencies of the factors related to fatigue, stress, and task performance;
- An annotated bibliography of current research on those factors and their inter-relationships;
- Identification of current known and hypothesized cause and effect methodologies for the estimation of stressor and moderator effects on cognitive and physical behaviors; and
- Example simulations demonstrating elements of those cause and effect methodologies.

We see the payoffs of the DREEMS effort as providing searchable and auditable sources of data and methodology for:

- Identification of risks, and quantification of uncertainty with respect to operational environment stressors;
- Analyses of current and proposed systems, methods, techniques, procedures, and training

protocols to mitigate the effects of stressors and otherwise enhance soldier performance;

- Development and application of expert systems to support pre- and trans-mission decision support aids with respect to human performance issues; and
- Identification and prioritization of known data gaps with respect to human performance.

## Author Biographies

**Victor E. Middleton** is a consultant working for Charles River Analytics (CRA) on the DREEMS SBIR Project. Dr. Middleton has over 30 years' experience working on human behavior representation, focusing primarily on modeling and simulation for small units and individual soldiers. He was one of the original developers of the Integrated Unit Simulation System (IUSS) for the U.S. Army Natick Soldier Research, Development & Engineering Center (NSRDEC), and served as principal scientist in re-engineering the IUSS as the agent-based Infantry Warrior IWARS simulation.

**Peter W. Weyhrauch** is a Vice President at CRA, leading its Human Effectiveness Division, which combines expertise in cognitive systems engineering, user interface design, simulation-based training and analysis, and software development to successfully integrate human operators with complex technologies. He also oversees the company's efforts in healthcare support and training, for preparing and providing decision support to clinical providers and healthcare organizations. Peter's primary research interests include simulation-based medical training, models of human performance, artificial intelligence, as well as scenario generation and computational narrative, a field which he helped to pioneer almost thirty years ago. He earned a BS in Computer Science and Engineering and a BS in Mathematics from the Massachusetts Institute of Technology, and an MS and a PhD in Computer Science from Carnegie Mellon University

**Spencer K. Lynn** is a Senior Scientist at CRA He uses computational models of signal detection and behavioral economics to investigate individual differences in perception, decision-making, and emotion, modeling those processes in software agents and investigating the breakdown of those processes in mental illness. Prior research has involved laboratory experiments and field observations across a diversity of organisms.

**Frank E. Ritter** is a professor of IST, of Psychology, and of CSE at Penn State. He researches the development, application, and methodology of cognitive models, particularly as applied to interface design, predicting the effect of behavioral moderators, and understanding and assisting learning. His books include one on applying cognitive models in synthetic environments (HSIAC, 2003), one on order effects on learning (2007, Oxford), contributions to a NRC report on how to use cognitive models to improve human-system design (Pew & Mavor, 2007) done for ARL, and has recently published a book on what psychology do systems designers (and modelers) need to know (Springer, 2014) with the Director of User Experience at Google.

**Christopher L. Dancy** is an assistant professor of computer science at Bucknell University. He researches the simulation of emotion and intelligence in artificial intelligence and intelligent agents, and their application. He also works on tying computational models of physiology to computational models of cognition. He has received a best paper award from the BRIMS conference on work in modeling the interaction of physiology and cognition.

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