MURI: Training Knowledge and Skills for the Networked Battlefield

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Final Report, 4/16/10

Positive Committee Comment

"The progress made during the past year has been significant. Positive response to the questions and requests of the committee in its report on the Third Annual Meeting of 2008 was evidenced."

Critical Committee Comments

(1) Experimental results

(2) IMPRINT, ACT-R, and Matlab modeling

(3) Quantitative framework

(4) Collaboration

(5) Translation into training process and transition

(1) Experimental Results

"The experimental results in the CU, CSU, and Purdue components were substantive and new and lead to new training principles/understanding. The committee questioned the considerable continuing emphasis on simple tasks and on the Simon effect but was glad to see greater consideration of more complicated tasks and effects closer to the 'networked battlefield'."

(1) Experimental Results

Our experimental research addresses fundamental cognitive processes and includes a range of simple to complex tasks. The Purdue component focuses on the simplest tasks in order to isolate the basic processes influenced by training. The Simon effect is used as a test bed that allows the influences of many factors corresponding to parameters of the quantitative model to be established. Over the years of the Training MURI, we have moved in the direction of more complex tasks that nevertheless can be studied in the laboratory. An understanding of training for complex environments, such as the networked battlefield, must be rooted in knowledge of the underlying elementary or component processes.

(2) IMPRINT, ACT-R, and Matlab Modeling

"(a) The modeling efforts used ACT-R and IMPRINT in innovative manners to generate hypotheses about quantitative frameworks and instance-based learning models.

(b) The modeling of the keystroke data entry task and the RADAR task in the Matlab code was stated to be about 10,000 times faster than ACT-R and IMPRINT codes on equivalent hardware. The committee indicated that the ACT-R and IMPRINT codes would be much faster if the ACT-R and IMPRINT coding had been done in a more compact manner. The committee questions why effort has been expended on the Matlab models. Even if the Matlab models turn out to be faster than the ACT-R and IMPRINT models, the use of Matlab seems to be mainly simply a computational issue with no significant basic research advantages."

(2) IMPRINT, ACT-R, and Matlab Modeling

(a) Matlab is being used by us as a tool for model evaluation, model comparisons, and parameter optimization. It is NOT being used by us as an alternative modeling tool. The Matlab versions of the data entry and RADAR tasks were equivalent and literal translations of IMPRINT models of performance in those tasks.

(b) If the panel knows how to vastly speed up ACT-R and IMPRINT by programming "in a more compact manner," that would be very valuable information to share with the ACT-R and IMPRINT communities in general and with our programmers in particular. The committee should be aware, however, that ACT-R runs in real time, mimicking the performance of real experimental subjects.

(2) IMPRINT, ACT-R, and Matlab Modeling (con't)

(c) The most essential aspects of the modeling evaluation effort in the MURI, right from the start, included assessing the prospects for "scalability" and "computability." These issues had previously been considered from within the ACT-R and IMPRINT environments, with unclear conclusions. Matlab offered a particularly easy means for getting right to the core of this fundamental "scalability and computability" issue. The point we are making is that there is a vast opportunity for performance improvements if a language such as Matlab is fully utilized for time consuming computations.

(d) In the RADAR task, one particular strength of Matlab (its super-fast array processing) was not applicable, but the relative speed advantage (compared to ACT-R and IMPRINT) held up just as well anyway.

(2) IMPRINT, ACT-R, and Matlab Modeling (con’t)

(e) With the much higher computational speeds now made available from the translation of IMPRINT models into Matlab code, one can run full parameter optimizations in the same time as it otherwise would take to run one single simulation. It is not far-fetched to believe that this facility will translate into basic research advantages. This advantage comes from the facility to establish optimal parameter values of existing models developed in other platforms.

(f) There are many fast scientific languages to choose among, and Matlab is merely one of them. We have chosen Matlab primarily because it is the easiest one for us to use, and thereby it allowed us to pay more attention to the key “scalability and computability” issues and less to low-level computational technicalities.

(3) Quantitative Framework

(a) "The quantitative framework and the instance-based learning model discussed by Raymond and Gonzalez are meaningful attempts to derive quantitative relations that incorporate training principles.

(b) The quantitative framework discussed by Fornberg does not include or make reference to training or cognitive principles and this work has not been integrated into the MURI team effort. Computational results of simulated annealing and genetic algorithms for parameter optimization can be useful. However, the most important aspects here are the basic research issues of in what spaces/manifolds and metrics the optimization is sought and the relation of these spaces/manifolds to the training principles derived by the MURI team."

(3) Quantitative Framework

Fornberg did not propose an alternative quantitative framework. His quantitative work was directed only to the issues of evaluating the models written by other members of the MURI team (in IMPRINT and ACT-R), comparing those models and finding optimal values for parameters in those models. Fornberg's work is deeply connected to the other aspects of the MURI. In particular, it is based on the ACT-R and IMPRINT models for data entry and RADAR. Specifically, the focus of this work was (a) comparison of the ACT-R and IMPRINT models for data entry and RADAR tasks, within which we have empirically established certain training principles, and (b) parameter optimization of the IMPRINT models. Finding optimal parameter values for a specific task-based model is of prime importance for understanding the fundamental cognitive processes required by the task. Moreover, all model evaluation efforts require parameter optimization.

(3) Quantitative Framework (con't)

(c) "The overall goal of the quantitative modeling is prediction. The modeling carried out so far by the MURI team does handle one predictability issue ('What is the effect of given training?'—modeling the outcomes of experiments) but does not yet directly handle the more important and deeper basic-research issue of predicting training requirements from the characteristics of the task to be trained.

The committee requests the MURI PI to summarize how the modeling efforts of the MURI, both in the past and in the future final year of the project, address the issue of predicting training requirements from the characteristics of the task to be trained."

(3) Quantitative Framework (con't)

IMPRINT is the Army's primary tool for predicting performance as a function of both the task to be trained and the conditions of training. Thus, we have focused on the formulation of performance shaping functions for IMPRINT that capture training principles. We have submitted some sample performance shaping functions for training principles that are mature and thoroughly empirically based. For those functions, we indicated the task taxons to which they are most likely to be applicable. Software developers will need to implement these functions within the IMPRINT platform.

ACT-R models are always task-dependent. The generalizability of a model across tasks is done at the theory level but not at the implementation level of a model. We have continuously used our ACT-R models for predicting the effects of training manipulations within a given task. The development of the Instance-Based-Learning modeling tool is a way of generalizing the conclusions from our modeling efforts.

(4) Collaboration

"The committee was glad to see evidence of value-added collaboration among a number of the cognitive-science and modeling portions of the MURI effort.
It is of concern to the committee that there are two efforts on quantitative frameworks ongoing at CU (Raymond and Fornberg) and these two efforts are completely disjoint. It is important that the PI of the Training MURI ensure that efforts on quantitative frameworks be carried out in a unified manner (unified both between themselves and with the cognitive science portion of the MURI) rather than effectively as two separate single-investigator projects."

(4) Collaboration

Fornberg did not present a third type of model. Instead, he presented an evaluation of models and a new way to optimize the parameter values in all models. The "Matlab model" referred to in his presentation was a literal translation of the IMPRINT model into the Matlab platform.

The efforts of Raymond and Fornberg are not disjoint or unrelated but, rather, are completely complementary. Fornberg presented an evaluation of detailed task-specific IMPRINT and ACT-R models. The IMPRINT models (which were translated literally into Matlab) like the ACT-R models capture the operation of the basic processes involved in training and account for demonstrable empirical effects of training principle variables.

The quantitative framework presented by Raymond gives us an abstract but mathematically coherent conception of the basic processes involved in training and at the same time of the influence of significant training principles on those processes.

(4) Collaboration (con't)

The outcomes of these two efforts (the computational and mathematical modeling) converge towards a full understanding of the fundamental issue, which is the prediction of performance as a function of training. Both of these efforts are derived from and provide an account of the same set of experimental results. In that sense these efforts are not disjoint but come together from different starting points, perspectives, and approaches.

(5) Translation into Training Process and Transition

"There was evidence of attempts to make principles translatable into the training process. A number of research directions, including but not limited to assessment of the value of automation in the training process and study of the clicker-testing technique, were of interest to the committee.

The movement toward transition is still weak. The discussion at the meeting about options, including but not limited to writing a manual of training principles, was of interest to the committee. The committee mentioned opportunities for additional funding for 'real' transition and described the need for the MURI team to position the basic research so that those opportunities could be realized."

(5) Translation into Training Process and Transition

Our transition effort is by no means limited to a manual of training principles. We described a number of other efforts that are underway, and we listed specific contacts that we have made for each of these efforts. We also asked the members of the government committee to give us their assessment of the value of those efforts to the Army, but we have gotten no response to this request. We have every expectation that the results of the MURI will be the basis for real transition to improved Army training. However, we need specific detailed feedback and advice on where the committee thinks our efforts are best focused.

(5) Translation into Training Process and Transition (Con't)

DOD, other governmental, and defense industry individuals or units with whom during the past year we have conducted the most extensive dialogues about possible transition are:

(1) SSRU Intelligent Tutoring Systems at ARI (Steve Goldberg: *Stephen.Goldberg@us.army.mil Phone: 407-384-3980)*

(2) Training of Pilots and Astronauts at NASA (Immanuel Barshi: *Immanuel.Barshi@nasa.gov Phone: 650-604-3921)*

(3) Air Force Office of Scientific Research (Dee Andrews: *Dee.Andrews@mesa.afmc.af.mil Phone:* 480-988-6561 x109*)*

DESCRIPTION AND HAND OUT OF TECHNICAL REPORTS

- Training Principles
- Taxonomy
- Performance Shaping Functions
- ACT-R Modeling (Visual Basic Version to use with Instance-Based Modeling)
- IMPRINT Modeling CD
- Model Assessment

ADDITIONAL TECHNICAL REPORTS

- **CU Experiments**
- **Purdue Experiments**
- **CSU Experiments**

COMPARISON OF GOALS AND ACCOMPLISHMENTS

(1) Develop and test training principles
(2) Understand the acquisition and retention of basic components of skill
(3) Explore levels of automation, individual differences, and team performance
(4) Perform a taxonomic analysis
(5) Develop predictive computational models
(6) Identify transitions to military training

SIGNIFICANT PUBLICATIONS BASED ON MURI RESEARCH

(1) 34 submitted manuscripts

(2) 50 peer-reviewed journal publications

(3) 29 chapters published in books or conference proceedings

(4) 125 presentations at professional meetings

(5) 8 masters theses and doctoral dissertations

OPEN DIALOGUE:

MURI TEAM AND GOVERNMENT COMMITTEE