Goals of Project

• Construct a theoretical and empirical framework for training

• Predict the outcomes of different training methods on particular tasks

• Point to ways to optimize training
Three Interrelated Project Components

(1) Experiments and data collection
   (a) Development & testing of training principles
   (b) Acquisition & retention of basic components of skill
   (c) Levels of automation, individual differences, & team performance

(2) Taxonomic analysis

(3) Predictive computational models
Training Principles

The MURI focuses on basic research aimed to identify and empirically support training principles. As Eduardo Salas and his colleagues of the Naval Training Systems Center have noted, there is an important distinction to be made among principles, guidelines, and specifications. These three mechanisms provide a conduit between training theory and training practice. A principle is an underlying truth or fact about human behavior. A guideline is a description of actions or conditions that, if correctly applied, could improve training. A specification is a detailed, precise statement of how training should be designed by operationalizing training guidelines in the development of training programs. Using these concepts, we view transition as the formulation of guidelines from principles, but it would be premature to skip from training principles directly to training specifications.
Organization of Present Meeting

(I) Introduction

(II) Progress in Fourth Year and Future Plans For Project
   (A) Experiments
   (B) Taxonomy & Quantitative Framework
   (C) Models
   (D) Plans for Future

(III) Caucuses and Feedback
MURI Principal Investigators and Co-Investigators

(1) University of Colorado (CU)
   Alice Healy, Principal Investigator
   Lyle Bourne, Co-Principal Investigator
   Bengt Fornberg, Co-Investigator
(2) Carnegie Mellon University (CMU)
   Cleotilde Gonzalez, Co-Investigator
(3) Colorado State University (CSU)
   Ben Clegg, Co-Investigator
   Eric Heggestad, Co-Investigator
(4) Purdue University (Purdue)
   Robert Proctor, Co-Investigator
MURI Research Associates and Graduate Research Assistants

(1) University of Colorado (CU)
   Bill Raymond, Research Associate
   Carolyn Buck-Gengler, Research Associate
   James Kole, Research Associate
   Michael Young, Graduate Student
   Shaw Ketels, Graduate Student
   Keith Lohse, Graduate Student
   Lindsay Anderson, Graduate Student

(2) Carnegie Mellon University (CMU)
   Varun Dutt, Graduate Student

(3) Colorado State University (CSU)
   Lisa Durrance Blalock, Graduate Student
   Heather Mong, Graduate Student
   Robert Gutzwiller, Graduate Student

(4) Purdue University (Purdue)
   Motonori Yamaguchi, Graduate Student
   Dongbin Cho, Graduate Student
   Yun Kyoung Shin, Graduate Student
   Jim Miles, Research Associate
MURI Research Consultants

Chris Wickens
University of Colorado and Alion Science

Matt Jones
University of Colorado
Meeting Presenters

(1) Overview and Coordination
  Healy, Bourne, Gonzalez, Lavery

(2) Experiments
  (a) Development & Testing of Training Principles
      Healy & Wickens
  (b) Acquisition & Retention of Basic Components of Skill
      Proctor
  (c) Levels of Automation, Individual Differences, & Team Performance
      Clegg & Heggestad

(3) Taxonomy, Quantitative Framework, and Modeling
  (a) Taxonomy, Quantitative Framework, and IMPRINT
      Raymond
  (b) ACT-R
      Gonzalez
  (c) Model Assessment
      Fornberg

(4) Plans for Future
  Bourne
Positive Committee Comment

The government committee is glad to see the scientific progress that has been made during the past year. The committee takes note of the existing collaboration among many parts of the MURI and of the fact that this collaboration has allowed scientific results to be achieved or to be envisioned that would not be possible without the collaboration. The transition of training principles to ARI Orlando and of performance-shaping functions to ARL/HRED during the past year is a positive start in the pursuit by the MURI team of transition opportunities. Much progress has been made so far.
Critical Committee Comments

(1) Need for a Global Quantitative Framework

(2) Issues Involving Scientific Approach

(3) Prioritization of Modeling Efforts

(4) Promoting Collaboration

(5) Transition Efforts
(1) Need for a Global Quantitative Framework

“To allow researchers and users to make sense out of the individual observations and principles, a global quantitative framework involving human-goal-based metrics is needed. Psychologists on the MURI team have to take a lead in the development of the global framework by recommending to the quantitative researchers candidate metrics and/or manifolds based on known or hypothesized human-factor knowledge. Embedding principles and other research results into global quantitative frameworks is essential as a tool for transition because potential transition partners need clear explanations of the meaning of the principles.”
(1) Need for a Global Quantitative Framework

The Training MURI team, together with Prof. Matt Jones, a mathematical psychologist in the University of Colorado Psychology and Neuroscience Department, drafted a document entitled "Unified Framework for Performance-Shaping Functions in Complex Tasks" on a quantitative framework for the effects of training variables on performance. We sent this document to John Lavery who forwarded it to members of the Government Committee. The draft is a work in progress, and we are revising and expanding it.

Lavery reported that the preliminary reaction of members of the Government Committee to the document “has been strong and positive.”
(2) Issues Involving Scientific Approach

“Up to the present, the principles developed by the MURI have all been generic principles. While these generic principles are of some interest, they do not answer the main question, namely, that of what training should be provided to which people. Each principle needs to be linked with major classes of training and trainees relevant for networked military operations. In the discussion at the meeting, these principles were called ‘predictive.’ It is important that the MURI team clarify how it will provide predictivity for categories of training and trainees, what experimental validation of predictivity will be carried out and how and when the predictivity will be embedded in IMPRINT and ACT-R modeling tools.”
(2) Issues Involving Scientific Approach

Performance shaping functions will be our mode to deliver predictivity in the IMPRINT platform. These functions are empirically validated and quantitatively expressed. At this point they are not embedded in IMPRINT, which is the Army’s primary prediction tool. Transition efforts need to be focused via a collaboration with the ARL (Aberdeen Proving Grounds). For each performance shaping function, we have specified the relevant task taxons to which the function applies. Thus, military tasks that include those taxons are assumed to be subject to the variable identified in the function.

We have investigated individual differences in intellectual ability, and we are presently addressing specifically the question of predictivity at the level of trainee category.
(3) Prioritization of Modeling Efforts

“IMPRINT modeling has taken considerable manpower but seems to be prioritized at a level lower than experimentation and ACT-R. The committee recommends prioritizing IMPRINT modeling higher.”
(3) Prioritization of Modeling Efforts

In our work, there are three distinctly different levels of IMPRINT modeling. (A) The level of modeling at which we have been working addresses cognitive processes for specific tasks, such as data entry and RADAR target detection. In this work we have shown that the general framework of IMPRINT modeling can be used to capture the details of specific cognitive processes in such tasks. (B) A second level of modeling using IMPRINT is that at which resource allocation is made in the military. Our performance shaping functions feed into that level of modeling. (C) Fornberg’s work on parameter optimization has been focused entirely on the IMPRINT models. Thus, we have been giving IMPRINT all the priority that we expressed in the original MURI grant proposal, and, given the difficulties encountered in Level A, we have made excellent progress.
(4) Promoting Collaboration

“While there has been significant and effective collaboration among some of the projects under this MURI, including for ACT-R modeling, more and more effective collaboration needs to take place. In particular, the committee noted that: (a) collaboration on IMPRINT modeling needs to be brought to a much higher level and (b) collaboration on developing a global quantitative framework needs to be established. Joint meetings, travel and communication among researchers will likely take place to promote collaboration.”
(4) Promoting Collaboration

There has been extensive collaboration among the various parts of the MURI team, and these collaborations have resulted in the achievement of valuable scientific, and potentially applicable, results. However, we think that collaboration per se is not the only factor to consider in deciding which projects to pursue in such a way as to maximize productivity and progress. For example, we decided that it would be better to develop an IMPRINT model of the CU fusion task rather than an IMPRINT model of the Purdue S-R compatibility task. An IMPRINT model of the S-R compatibility task would increase collaboration between CU and Purdue. But such a model would be a relatively minor increment given the comparison of IMPRINT and ACT-R models already existing for the data entry and RADAR tasks. The fusion task allows us to go beyond the level of data to the level of information and to simulate in a more realistic way vital aspects of the networked battlefield.
(5) Transition Efforts

“The items listed as transitions (manual of empirically-based training principles, taxonomy, integrated set of ACT-R cognitive models, models in IMPRINT, comparative evaluation of ACT-R and IMPRINT models) were primarily scientific goals rather than transitions. Achievement of these scientific goals can lead to transition but they are not by themselves transition. Proactive identification of mature basic research results and proposing to government and defense industry personnel the implementation of these results in specific government and defense industry programs that need the results is a responsibility of the MURI team.”
(5) Transition Efforts

The items listed in this comment were the ones we presented at the 2007 meeting. We presented them again at the 2008 meeting only as reminders because not everyone was present at the 2007 meeting. In addition, we highlighted in the 2008 meeting three specific points of transition that were the focus of our 2008 add-on proposal:

1. Our training principles can be embodied in intelligent tutoring programs including those for knowledge domains that are not well specified.

2. We have developed quantitative performance shaping functions that expand IMPRINT modeling currently used by the Army for prediction purposes to include training parameters.

3. We can apply our principles to the training of operators of unmanned aerial vehicles.
(5) Transition Efforts (Continued)

DOD, other governmental, and defense industry individuals or units who have expressed interest in our principles and with whom we have initiated a dialogue about possible transition are:

(1) SSRU Intelligent Tutoring Systems (Steve Goldberg: Stephen.Goldberg@us.army.mil Phone: 407-384-3980)
(2) West Point Information Integration (James Merlo: James.Merlo@usma.edu Phone: 845 938 5902)
(3) Astronaut Training (Immanuel Barshi: Immanuel.Barshi@nasa.gov Phone: 650-604-3921)
(4) Air Force Office of Scientific Research (Jun Zhang: jun.zhang@afosr.af.mil Phone: 703-696-8421)
Significant Meetings Related to Army Training over Last Year

(1) Gonzalez & Clegg, Visit to SSRU
   January 2009, Orlando, FL

(2) Healy & Bourne, SEP
   April-May 2009, Boulder, CO
Significant Publications Based on MURI Research Over the Last Year

(1) 12 submitted manuscripts
(2) 22 peer-reviewed journal publications
(3) 12 chapters published in books or conference proceedings
(4) 29 presentations at professional meetings
(5) 2 masters theses
Development and Testing of Training Principles: Completed Experiments

(1) Tests of the generality across tasks of individual principles
(2) Tests of multiple principles in a single task
(3) Tests of principles in complex, dynamic environments
(4) Developing and testing new principles
Serial Position Principle

Retention is best for items at the start of a list (primacy advantage) and at the end of a list (recency advantage).
Procedure

• 48 trials
• 7-item sequences
• One optimal deployment location
• Sequential presentation
• Free recall
Imagine you are a military intelligence analyst. You are on the battlefield testing team for a new micro unmanned aerial vehicle (UAV, Figure 1).

Your mission is to evaluate the placement and threat level of enemy forces in order to inform remote pilots of the best locations to deploy these UAV units.

You will see a grid representing a battlefield. After a green x flashes at the center of the grid, a series of red blips representing enemy forces will light up. These blips will appear and disappear one at a time on the screen. The shade of the blip will represent that enemy’s threat level. There are four levels of enemy threat, with squares that are more deeply red representing a relatively greater threat level than those that are less red.

Your goal is to choose a location on the battlefield at which to place the UAV from which it can gain the greatest amount of useful information possible about all enemies on the battlefield. Because the sensors on this UAV that are used for data gathering have a limited range, the closer the UAV is to an enemy location, the more information it can gain about it. However, it is imperative to retrieve more intelligence information from enemies that represent a greater threat. Thus, the best location for the UAV should take into account gaining more information about greater threats while still gaining as much information as possible about all threats. Keep in mind that each scenario has a unique best location for UAV deployment.

To carry out your mission, pay close attention to the exact locations of enemies as they are presented on the screen one at a time. After seeing all of the enemies in a series, you must immediately make a decision as to the battlefield position that represents the single most useful UAV placement, and use the
Design

Within-Subjects Variables

Serial Position (1-7)

Block (1-4)
Principle of Testing

A test can strengthen a person’s knowledge of material as much as, or possibly even more than, can further study.

Principle of Training Compression

Training can be truncated by eliminating practice on known facts.
Procedure

• Facts about unfamiliar countries
• 8 facts about 8 countries
  • Niger’s major agricultural product is cowpeas
• Cued recall tests
  • Niger’s major agricultural product is ___?
• 4 study-test rounds
• 1st and 4th rounds involve all 64 facts
• 2nd and 3rd rounds involve fewer facts in some conditions
• Full-study, Dropout, Yoked, Clicker 25, Clicker 40, Clicker D
Design

**Between-Subjects Variable**
Training Condition
(Full-Study, Dropout, Yoked, Clicker 25, Clicker 40, Clicker D)

**Within-Subjects Variable**
Training Round
(First and Fourth Study-Test Rounds)
Strategic Use of Knowledge Principle

Learning and memory are facilitated whenever pre-existing knowledge can be employed, possibly as a mediator, in the process of acquisition.
Procedure

• **Listing Phase**
  List names of 12 familiar people (3 female friends, 3 female relatives, 3 male friends, 3 male relatives)

• **Learning Phase**
  Learn 144 fabricated facts, 12 facts about 12 people
  (e.g., Linda Hanley drives a Chevy)
  3 study-test rounds
  High Knowledge - facts about familiar people listed
  Low Knowledge - facts about unfamiliar people

• **Test Phase**
  cued recall (e.g., Linda Hanley drives a ____?)
  immediate and retention (1-week delay)
Design

Between-Subjects Variable

Knowledge Condition
  (High Knowledge, Low Knowledge)

Within-Subjects Variables

Relation
  (Friends, Family)

Training Round
  (1-3)

Test Time
  (Immediate, Retention)

Dependent Variables

Accuracy (proportion correct)

Response Time (log ms)
Principle of Bilateral Transfer

For spatial motor skills, there is more transfer from the dominant to the non-dominant hand than in the opposite direction.

Principle of Mental Practice

Mental practice promotes task-level representations but not effector-level representations of motor skill.
Procedure

• 8 characters
  • 4 letters (A, K, M, E)
  • 4 corresponding symbols (alpha, kappa, mu, epsilon)
• Baseline: Subjects wrote each character eight times with one hand (dominant or non-dominant)
• Distractor task: Subjects performed a letter detection task
• Practice: Subjects wrote each character as many times as they could in 1 minute using the alternate hand as used in baseline
• Transfer: Subjects wrote each character as many times as they could in 1 minute using the same hand as used in baseline
• The first 8 characters written in each minute were used for time and size measurements
Design

Between-Subjects Variables

Order
(NDN, DND)

Practice Condition
(Mental, Physical)

Within-Subjects Variables

Phase
(Baseline, Practice, Transfer)

Dyad
(Letter, Symbol)
Development and Testing of Training Principles

(1) Tests of the generality across tasks of individual principles
(2) Tests of multiple principles in a single task
(3) Tests of principles in complex, dynamic environments
(4) Developing and testing new principles

Serial Position Principle
Principle of Testing
Principle of Training Compression
Strategic Use of Knowledge Principle
Principle of Bilateral Transfer
Principle of Mental Practice
SUMMARY, PLANS FOR THE FUTURE, AND DIALOGUE
SUMMARY

1. Experiments

2. Quantitative Framework

3. Modeling (IMPRINT, ACT-R, Matlab)
PLANS FOR THE FUTURE

Complete experiments and papers
Complete taxonomy, incorporating performance shaping functions
Prepare manual of training principles
Prepare a summary report of modeling comparison, model evaluation, and model optimization tools
Complete efforts to transition work to applied settings
OPEN DIALOGUE:
MURI TEAM AND GOVERNMENT COMMITTEE