MURI: Training Knowledge and Skills for the Networked Battlefield
ARO Award No. W9112NF-05-1-0153

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Benjamin Clegg, Bengt Fornberg, Cleotilde Gonzalez, Eric Heggestad, Ronald Laughery, Robert Proctor, Co-Investigators
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

(2) Taxonomic analysis

(3) Predictive computational models
Organization of Present Meeting

(I) Introduction

(II) Progress in First Year and Future Plans For Project
   (A) Experiments
   (B) Taxonomy
   (C) Models

(III) Summary and Reactions
MURI Personnel

(1) University of Colorado (CU)
   Alice Healy, Principal Investigator
   Lyle Bourne, Co-Principal Investigator
   Bengt Fornberg, Co-Investigator
   Ron Laughery, Consultant
   Bill Raymond, Research Associate
   Carolyn Buck-Gengler, Research Associate

(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
Meeting Presenters

(1) Overview and Coordinate
   Healy & Bourne

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

(3) Taxonomy
   Raymond

(4) Models
   (a) ACT-R
       Gonzalez
   (b) IMPRINT
       Buck-Gengler
   (c) Model Assessment
       Fornberg
Key Comments from Government Committee

(1) The MURI team should present its plan and rationale for dealing with taxons and complex tasks and is encouraged to complete the planning matrix as soon as possible.

(2) The project should maintain focus on training and prevent "scope creep" into related issues such as the distal environment.

(3) Data-tractability and computational tractability are important.

(4) The medium of delivery in tasks and in training is important. A number of major new options that are currently being proposed to DoD (perhaps WWW, immersive simulation, tactile information presentation, etc.) need to be considered and prioritized according to need and scientific feasibility.

(5) The path for creating ACT-R models is clear but the path for creating IMPRINT models is not clear.

(6) Connections with related ongoing efforts at ARL, AFRL and universities that are not represented on this MURI team should be increased.

(7) Publishing in peer-reviewed journals is a major way in which the Training MURI will disseminate its results. At the same time, working IMPRINT and ACT-R models need to be written.
Key Comments from Government Committee

(1) The MURI team should present its plan and rationale for dealing with taxons and complex tasks and is encouraged to complete the planning matrix as soon as possible.

(1) We completed a preliminary planning matrix, which includes both training method and task type taxons. This matrix is compatible with the taxonomic requirements of IMPRINT. We presented the matrix to Jonathan Kaplan of the ARI, Susan Archer of Micro Analysis and Design (MA&D), and John Lavery of the ARO during his February 2006 Boulder site visit. All recipients responded favorably to this development.
Key Comments from Government Committee

(2) The project should maintain focus on training and prevent "scope creep" into related issues such as the distal environment.

(2) We are examining the effects of modality on information processing and retention, but we are not examining more distal aspects of the environment. We are maintaining focus on the goals of the project as outlined in the proposal and not expanding into extraneous or satellite issues.
Key Comments from Government Committee

(3) Data-tractability and computational tractability are important.

(3) We have been concerned with this issue from the beginning. Bengt Fornberg will expand on this.
Key Comments from Government Committee

(4) The medium of delivery in tasks and in training is important. A number of major new options that are currently being proposed to DoD (perhaps WWW, immersive simulation, tactile information presentation, etc.) need to be considered and prioritized according to need and scientific feasibility.

(4) We have included all training options in our taxonomy and are attempting to stay alert to new developments regarding the medium of delivery (e.g., as discussed in papers for the Army Science of Learning Workshop). To date, however, our experiments have not compared old and new methodologies for their relative efficacy, with the exception of Proctor’s comparison of laboratory and simulation environments.
Key Comments from Government Committee

(5) The path for creating ACT-R models is clear but the path for creating IMPRINT models is not clear.

(5) We responded to this criticism in three ways: (a) We sent Bill Raymond to an IMPRINT workshop in Alexandria in December. He made a presentation at the meeting summarizing the Training MURI and its plans for developing IMPRINT models for training, and he learned about other projects involving IMPRINT modeling. (b) Postdoctoral Research Associate Carolyn Buck-Gengler was assigned the role of primary IMPRINT model developer. (c) Both Raymond and Buck-Gengler attended a 4-day IMPRINT class held at MA&D facilities in Boulder. (d) We have created an IMPRINT model for digit data entry, the same task being modeled in ACT-R.
Key Comments from Government Committee

(6) Connections with related ongoing efforts at ARL, AFRL and universities that are not represented on this MURI team should be increased.

(6) Raymond attended the ARL-sponsored IMPRINT workshop, and Healy attended the ARI-TRADOC-sponsored Army Science of Learning workshop. We have discussed the Predator project with MA&D investigators, who have attended some of our weekly lab meetings. We are also in occasional contact with Steve Goldberg at SSRU in Orlando.
Key Comments from Government Committee

(7) Publishing in peer-reviewed journals is a major way in which the Training MURI will disseminate its results. At the same time, working IMPRINT and ACT-R models need to be written.

(7) We are continuing to publish regularly in peer-reviewed journals. In addition, modeling work is on-going, and software for those models will be made available at an appropriate time in the future.
Significant Meetings over Last Year

(1) Raymond, IMPRINT Workshop
   December, Alexandria

(2) Raymond & Buck-Gengler, 4-day IMPRINT class
   December, MA&D

(3) Lavery, site visit
   February, Boulder

(4) Healy, Army Science of Learning Workshop
   August, Hampton
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
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.
Association Training

- Participants associated 36 4-digit numbers with familiar individuals, unfamiliar individuals, or with nothing.
- Study-test procedure

Example:
Familiar Individual: 1256 Jonathan Kaplan
Unfamiliar Individual: 9571 Linda Hanley
Nothing: 3849 Blank
Data Entry Task

• Two blocks of the data entry task
• Each with 36 old numbers as well as 36 new numbers.

Recognition Test

• Participants saw 36 old numbers and 36 completely new numbers
• New/Old judgment
The bar chart illustrates the association type with different values of $d'$. The chart shows a significant difference in association type between familiar and unfamiliar conditions.
Specificity of Training Principle

Retention and transfer are depressed when conditions of learning differ from those during subsequent testing.

Variability of Practice Principle

Variable practice conditions typically yield larger transfer effects compared with constant practice conditions.
Design and Procedure

Experiment 1

- Trained on 2 dimensions
  - pure horizontal + a diagonal
    (2, 6, 1, 5 or 2, 6, 3, 7)
  - pure vertical + a diagonal
    (4, 8, 1, 5 or 4, 8, 3, 7)
- Tested on all dimensions

Experiment 2

- Trained on 1 dimension
  - pure horizontal (2, 6)
  - pure vertical (4, 8)
  - diagonal (1, 5)
  - diagonal (3, 7)
- Tested on all dimensions
Testing on Diagonal Targets

- Experiment 1 (train on 2 dimensions) New
- Experiment 1 (train on 2 dimensions) Old
- Experiment 2 (train on 1 dimension) New
- Experiment 2 (train on 1 dimension) Old

Block Movement Time (in s)
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).

List Length Principle

Retention of a given item in a list is better for short lists than for long lists.
Design and Procedure

List Lengths 6 to 15 Targets

Number of Distractors = Number of Targets

Criterion = 2 Perfectly Recalled Sequences in a Row
All Trials Until Criterion
Training Difficulty Principle

Any condition that causes difficulty during learning may facilitate later retention and transfer.
Design

Between-Subjects Variables
Condition Week 1 (Tone, Silent)
Condition Week 2 (Tone, Silent)
Half of the subjects same condition both weeks
Half of the subjects different conditions each week
Target Type (Digits, Letters)

Within-Subjects Variables
Number of Targets/Number of Filled-in Blips (1+1, 4+4)
Mapping: Consistent (CM)/Varied (VM)
Session Half (First 4 blocks/Second 4 blocks)
Training

Response Time (in ms)

Targets + Blips

- 1+1
- 4+4

Mapping

Consistent

Varied
Testing

<table>
<thead>
<tr>
<th>Testing Condition</th>
<th>Response Time (in ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test-Silent</td>
<td>600</td>
</tr>
<tr>
<td>Test-Tone</td>
<td>800</td>
</tr>
<tr>
<td>Train-Silent</td>
<td>1000</td>
</tr>
<tr>
<td>Test-Tone</td>
<td>1200</td>
</tr>
</tbody>
</table>
Testing

Response Time (in ms)

- Consistent Varieties
- Train-Silent
- Train-Tone
- Variance

Mapping

- Consistent
- Varied
Mental Rehearsal Principle

Mental rehearsal can retard forgetting and promote transfer of training to a larger extent than can physical rehearsal, which suffers from motoric interference.
Experimental Phases

Week 1
- Familiarization (5 blocks of 64 numbers)
- Immediate Test (32 old and 32 new numbers)

Week 2
- Refresher Training Part 1 (5 blocks of 64 numbers)

Week 3
- Refresher Training Part 2 (5 blocks of 64 numbers)

Week 4
- Delayed Test (32 old and 32 new numbers)
- Recognition Test (32 old and 32 new numbers)
Design

Between-Subjects Variable

Training Condition (Physical, Imagery Grip)

Within-Subjects Variables

Test (Immediate, Delayed)
Number Type (Old, New)
### Old Items

- **Training Condition**
  - **Execution Time (in s)**: 0.30, 0.35, 0.40, 0.45, 0.50
  - **Immediate**
  - **Delayed**

### New Items

- **Training Condition**
  - **Execution Time (in s)**: 0.30, 0.35, 0.40, 0.45
  - **Immediate**
  - **Delayed**

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The graphs illustrate the execution time in seconds for old and new items under different training conditions: Imagery-Grip and Physical. The bar charts show a comparison between immediate and delayed conditions.
Organization of Present Meeting

(I) Introduction

(II) Plans For Project and Progress So Far
   (A) Experiments
   (B) Taxonomy
   (C) Models

(III) Summary and Reactions
Data Entry Experiments

Task: Subjects see a 4-digit number, and they type it on a computer keypad.

Design: In each session half, subjects see and type 5 blocks of 64 numbers.

Measures: Both typing accuracy (proportion correct) and typing speed (total response time) are measured. Also, component measures (error types and separate times for each key press) are examined.
Data Entry Task: Sample Principles Illustrated in Completed Studies

Specificity of Training Principle
Retention and transfer are depressed when conditions of learning differ from those during subsequent testing.

Procedural Reinstatement Principle
Duplicating procedures required during learning facilitates later retention and transfer.

Depth of Processing Principle
Activities during training that promote deep and elaborate processing enhance durability of training.

Cognitive Antidote Principle
Adding cognitive complications to a routine task overcomes decline in accuracy due to fatigue.
Data Entry Task: Variables Manipulated

(1) Training Trial, Block, and Session
(2) Repetitions of Numbers to Be Typed
(3) Keys Used During Training and Testing (computer row, computer keypad, telephone keypad)
(4) Format of Numbers to be Typed (word, numeral)
(5) Availability and Duration of a Rest Break during Training
(6) Old and New Numbers during Testing
(7) Verbalization (silent, relevant, irrelevant)
(8) Added Cognitive Tasks (multiplication, coding)
(9) Presence of Feedback
(10) Presence of Wrist Weights
(11) Reading Numbers, Typing Numbers, Using Motor Imagery during initial or refresher training
(12) Response Format (digits or initial letters of numbers)
(13) Hand Used for Typing during Training and Testing
Summary of Response to Government Committee Comments

(1) The MURI team should present its plan and rationale for dealing with taxons and complex tasks and is encouraged to complete the planning matrix as soon as possible.

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