Training: Automation and Aptitude

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Overview

• Automation
• Task Performance
  ▪ Automation groups
• Cognitive Abilities
  ▪ Ability and automation
• Continuing work
• What is automation?
  "a device or system that accomplishes (partially or fully) a function that was previously carried out (partially or fully) by a human operator."
(Wickens, Mavor, Parasuraman, & McGee, 1998)
Automation

• Ever increasing introduction of automation
  ▪ Improved performance & safety
  ▪ Efficiency (fewer people doing more jobs)
  ▪ Support of the person
Automation on the networked battlefield
Automation

- Automation need not be an all or none thing
- Variety of types of automation
  - Concept of Levels of Automation
    - Sheridan & Verplank (1978)
10. The computer decides everything and acts autonomously, ignoring the human.
9. informs the human only if it, the computer, decides to
8. informs the human only if asked, or
7. executes automatically, then necessarily informs the human, and
6. allows the human a restricted time to veto before automatic execution, or
5. executes that suggestion if the human approves, or
4. suggests one alternative, and
3. narrows the selection down to a few, or
2. The computer offers a complete set of decision/action alternatives, or
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It appears you are trying to give a presentation.

Would you like to:

- Have me block something on the screen?
- Have your train of thought interrupted?
- Unexpectedly find your typing is being entered as a help query?
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5. executes that suggestion if the human approves, or

6. allows the human a restricted time to veto before automatic execution, or

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7. executes automatically, then necessarily informs the human, and
6. allows the human a restricted time to veto before automatic execution, or
5. executes that suggestion if the human approves, or
4. suggests one alternative, and
3. narrows the selection down to a few, or
2. The computer offers a complete set of decision/action alternatives, or
1. The computer offers no assistance: the human must take all decisions and actions.
6. Computer suggests one action, and executes automatically but allows the human a restricted time to veto before automatic execution, or

5. executes that suggestion if the human approves, or

4. suggests one alternative, and

3. narrows the selection down to a few, or

2. The computer offers a complete set of decision/action alternatives, or

1. The computer offers no assistance: the human must take all decisions and actions.
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2. The computer offers a complete set of decision/action alternatives, or

3. Narrows the selection down to a few, or

4. Suggests one alternative, and

5. Suggestion of one action, and executes if the human approves

6. Allows the human a restricted time to veto before automatic execution, or

7. Executes automatically, then necessarily informs the human, and

9. Informs the human only if asked, or

10. Informs the human only if it, the computer, decides to

6. Computer suggests one action, and executes automatically but allows the human a restricted time to veto before automatic execution
1. The computer offers no assistance: the human must take all decisions and actions.

2. The computer offers a complete set of decision/action alternatives, or

3. Narrows the selection down to a few, or

4. Suggests one alternative, and

5. Suggestion of one action, and executes if the human approves

6. Computer suggests one action, and executes automatically but allows the human a restricted time to veto before automatic execution

7. Executes automatically, then necessarily informs the human, and

8. Informs the human only if asked, or

9. Informs the human only if it, the computer, decides to

10. The computer decides everything and acts autonomously, ignoring the human.

Key difference: Who initiates automation?
1. The computer offers no assistance: the human must take all decisions and actions.

2. The computer offers a complete set of decision/action alternatives, or

3. narrows the selection down to a few, or

4. suggests one alternative, and

5. allows the human a restricted time to veto before automatic execution, or

6. executes automatically, then necessarily informs the human, and

7. informs the human only if asked, or

8. informs the human only if it, the computer, decides to

9. in any case informs the human.

10. The computer decides everything and acts autonomously, ignoring the human.

Key difference: Who initiates automation?
1. The computer offers no assistance: the human must take all decisions and actions.

2. The computer offers a complete set of decision/action alternatives, or

3. Narrows the selection down to a few, or

4. Suggests one alternative, and

5. Suggestion of one action, and executes if the human approves

6. Allows the human a restricted time to veto before automatic execution, or

7. Executes automatically, then necessarily informs the human, and

8. Informs the human only if it, the computer, decides to

9. Informs the human only if asked, or

10. The computer decides everything and acts autonomously, ignoring the human.
1. The computer offers no assistance: the human must take all decisions and actions.

2. The computer offers complete assistance to the human for decision and actions.

3. Narrows the selection down to a few.

4. The computer offers a complete set of decision/action alternatives.

5. Suggestions one action, and executes if the human approves.

6. Computer suggests one action, and executes automatically but allows the human a restricted time to veto before automatic execution.

7. Executes automatically, then necessarily informs the human, and informs the human only if asked, or executes automatically, then necessarily informs the human, and informs the human only if it, the computer, decides to.

10. The computer decides everything and acts autonomously, ignoring the human.
Training

- Automation during training
  - Naturally present in the system
  - Guide learning
  - Better performance from novices
Negative consequences

• Automation might:
   Mask operator shortcomings
   Restrict exposure to certain system states
   Reduce learning (“Out of the loop”)
   Add to workload (remember to engage automation)
Task

- Simulated Orange Juice Pasteurizing Plant
  - Interaction of 3 subsystems
  - Presence of competing goals
  - Dynamics incorporate time lags

Hope these capture some of key elements of a future networked battlefield context
Method

• 3 conditions
  ▪ No automation (full manual control)
  ▪ User-initiated automation
  ▪ Auto-initiated automation (with veto option)

• Two sessions of training
  ▪ 10 trials per session for 2 days

• Final test without automation
Initial findings
Initial findings

Performance Across Training

Units of Good Juice

Manual Control
User Activated Auto
Auto Activated Auto

Day 1
Block 1
Block 2

Day 2
Block 1
Block 2
Initial findings

Automation improves initial performance

Performance Across Training

<table>
<thead>
<tr>
<th>Units of Good Jr</th>
<th>Manual Control</th>
<th>User Activated Auto</th>
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<tbody>
<tr>
<td>DAY 1 Block 1</td>
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<tr>
<td>DAY 1 Block 2</td>
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<tr>
<td>DAY 2 Block 1</td>
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<tr>
<td>DAY 2 Block 2</td>
<td></td>
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</tbody>
</table>
Initial findings

Performance Across Training

- Manual Control
- User Activated Auto
- Auto Activated Auto

Units of Good Juice

Day 1

Day 2
Initial findings

Both levels of automation look the same

Units of Good Juice

Block 1  |  Block 2  |  Block 1  |  Block 2

DAY 1    |            | DAY 2     |            

Manual Control  |  User Activated Auto  |  Auto Activated Auto
Initial findings

By end of training, no differences
Quick summary

• Suggests benefits from automation
  ▪ Novice operators do better at first
• No difference between the type of automation

• Next look at performance when automation is removed
Removing automation

Transfer - Underlying Knowledge

Units of Good Juice

Manual Control

User Activated

Auto Activated
Removing automation

Transfer - Underlying Knowledge

Units of Good Juice

Manual Control

User Activated

Auto Activated

Colorado State University

UNC Charlotte
Removing automation

No significant cost of removing user activated automation

- Manual Control
- User Activated
- Auto Activated
Removing automation

Evidence of operator dependence on automation

- Manual Control
- User Activated
- Auto Activated
Summary of findings

- Evidence that automation changes learning and performance
- Operator-initiated version linked to superior ultimate knowledge of the system
Contribution

One ongoing issue in our research:

• How should automation fit into the MURI *training x task* matrix?
Individual Differences

- Standardized training is not equally effective for everyone
  - Skill acquisition
  - Transfer of training
Phases of learning

• Long-standing idea that complex task learning progresses through 3 phases
  ▪ Declarative knowledge
  ▪ Knowledge compilation
  ▪ Procedural
  • Anderson 1982; Fitts & Posner, 1967; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977
Ackerman (1988)

- Distinct cognitive ability dimensions related to performance of learners in each of 3 phases
  - General cognitive ability = declarative knowledge
  - Perceptual speed abilities = knowledge compilation
  - Psychomotor abilities = procedural
Battery

Educational Testing Service’s Kit of Factor-Referenced Cognitive Tests

- Two tests for specific ability dimensions
  - Reasoning Ability
  - Quantitative Ability
  - Verbal Ability
  - Visual Scanning Ability
  - Perceptual Speed Ability
- General cognitive ability \((g)\)
  - Factor scores from the first, unrotated principle factor
- Abilities assessed are similar to abilities assessed in the ASVAB
Abilities & Automation

- Examined whether the relationship between $g$ and performance was different within each condition
  - i.e., did level of automation impact the $g$—performance relationship?

- Expected the relationship to be …
  - Strongest in the manual control condition early in training
    - Highest cognitive demands on the learner here
  - Similar across conditions later in training
• Conducted a series of moderated regressions
  ▪ Predictors included:
    • Two dummy variables for automation condition
    • \( g \)
    • Two interaction terms

  ▪ Again, focus today on Good Juice as the DV
Let’s take a look

Initial Acquisition Performance

- Results of moderated regression on amount of good juice produced in Day 1 Block 1
Different intercepts indicate that the Manual Control people made less good juice (statistically different from other two groups)
General upward slope within each condition indicates higher levels of $g$ are associated with more good juice (statistically significant main effect)
$g$—performance relationship stronger in the manual control group than in the user activated group (statistically significant interaction)
Quick summary

• Higher $g$ scores (general cognitive ability) associated with better initial performance in the task
  ▪ Matches with previous findings in other domains

• Presence of automation may serve to lessen the influence of $g$
Further analyses

Final training
  - Day 2 Block 2 good juice production

Underlying knowledge (no automation transfer)
  - Good juice production on transfer trial
Day 2 Block 2 Good Juice

- No main effect for condition
Day 2 Block 2 Good Juice

- No main effect for condition
- Main effect for $g$

![Graph showing the relationship between Day 2 Block 2 Good Juice and $g$. The graph indicates that there is a significant effect for $g$, with different conditions represented by distinct lines.](image)
Day 2 Block 2 Good Juice

- No main effect for condition
- Main effect for $g$

No main effect for condition
Main effect for $g$
Day 2 Block 2
Good Juice

- No main effect for condition
- Main effect for $g$
Day 2 Block 2 Good Juice

- No main effect for condition
- Main effect for $g$
- Significant interaction … $g$—performance relationship stronger in the manual control group than in the user activated group
Day 2 Block 2 Good Juice

- No main effect for condition
- Main effect for $g$
- Significant interaction … $g$—performance relationship stronger in the manual control group than in the user activated group
Quick summary

• $g$ remains important in this task even this far into training
  ▪ One possibility is that this is a product of the “trial and error” nature of learning

• Capability to initiate automation to help you out appears to lessen the influence of $g$
Good Juice Transfer Trial

• No main effect for condition (though really close between MC and UA; effect is reduced in full model)
Good Juice TransferTrial

• No main effect for condition (though really close between MC and UA; effect is reduced in full model)

• Main effect for $g$
Good Juice Transfer Trial

- No main effect for condition (though really close between MC and UA; effect is reduced in full model)
- Main effect for g
- No condition by g interaction
A final quick summary

- Underlying knowledge of the system derived relates to $g$
- Previous relationship between type of automation and $g$ disappear when the automation itself is removed
Conclusions

• $g$ is an important predictor of early and late performance

• $g$—performance relationship differs by condition
  ▪ Stronger relationship in the MC condition than in the user activated condition
  ▪ Surprising … found in 4th block as well!
Conclusions

- Some suggestion that the presence of automation may reduce differences related to aptitude during training
- However, automation did not impact these same differences in relation to underlying knowledge of the system
- Want to look at these relationships with a more complex task, with stronger ability demands
Next Steps

• Examine mental models, plus frequency of automation use, trust and self-confidence ratings
  ▪ e.g., Do high g individuals activate automation less often?

• Effects of the combination of levels of automation and cognitive abilities
  ▪ Goal of matching automation to the learner
Responding to last year’s feedback

Issue

1.) Integration across the MURI teams
Responding to last year’s feedback

Issue

1.) Integration across the MURI teams
   - Next step is to look at MURI principles in relation to automation
Responding to last year’s feedback

• Next experiment: Fixed versus varying levels of automation in training
  ▪ Contextual interference = Mixed → More effective learning
  ▪ Procedural reinstatement = Mixed → Less effective learning
Responding to last year’s feedback

Issue

2.) Map MURI findings into more obvious “direct military task relevance”
Responding to last year’s feedback

Issue

2.) Map MURI findings into more obvious “direct military task relevance”

- Reminder of the MURI team’s general approach – investigate principles that will apply to (as yet unspecified) future networked battlefield technologies
Responding to last year’s feedback

Issue

2.) Map MURI findings into more obvious “direct military task relevance”

- Also conducted some preliminary work to help begin mapping some previous MURI findings and ideas into another task
Marksmanship

• Training shooting skills
Marksmanship

- Training shooting skills
Two conditions

- Implicit
  - Just begin the task
- Explicit
  - Given a marksmanship manual to read through prior to shooting
Pilot Data

Explicit vs Implicit Marksmanship

Explicit Instruction

Implicit Learning

Percentage Hits

Last training  Speeded Test 1  Speeded Test 2
Pilot Data

Explicit vs Implicit Marksmanship

<table>
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- Implicit Learning
- Explicit Instruction

- Last training
- Speeded Test 1
- Speeded Test 2
Pilot Data

Explicit vs Implicit Marksmanship

Implicit Learning
Explicit Instruction

Percentage Hits

Last training Speeded Test 1 Speeded Test 2
Individual Differences

• Building Individual Differences into this task
  ▪ State Anxiety (Speilberger, 1968 & 1977)
Best and the worst

• State Anxiety (Speilberger, 1968 & 1977)
  ▪ Low (≤ 60)
  ▪ High (≥ 70)
Very Preliminary…

First 20 speed test trial shots

Percentage Target Hits

Low  High

Anxiety
No conclusions

• At this point, just looking at the viability of this type of task
Overall CSU Progress

• Completed our first large-scale individual differences study
  ▪ Exactly on schedule
• Begun looking at transition of ideas to strongly military-relevant domains
• Future issue: Option years to expand work to team situations