Training: Automation and Aptitude

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Overview

• General background
• Study 1
  ▪ Automation groups
• Study 2
  ▪ Varying automation in training
• Additional Experiment
  ▪ Timing and types of advice
Future warfighters will interact with a variety of new forms of technology...
...which will place new demands on the warfighter
Automation can support the operator…
...or it can get in the way!
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 three subsystems
  - Presence of **Competing Goals**
  - **Dynamics** incorporate time lags
Study 1

- Central issue: Does automation improve learning in training?
Method

3 conditions

• Manual Control
  ▪ No automation

• Automatically-initiated automation
  ▪ Automation adopts control of subsystem unless vetoed

• User-initiated automation
  ▪ Operator can choose to relinquish control
Method

Two sessions of training
• 10 trials per session for 2 days
  ▪ Reported as 2 blocks of 5 trials per day

Transfer trial (= no automation)
Results: Across training
Results:
Across training
Results:
Across training

Automation improves initial performance

- Manual Control
- User Activated Auto
- Auto Activated Auto
Results: Across training

Both levels of automation look the same
Results: Across training

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

![Bar chart showing units of good juice for manual control, user activated, and auto activated.](chart.png)
Removing automation

No significant cost of removing user activated automation

<table>
<thead>
<tr>
<th>Units of Good Juice</th>
</tr>
</thead>
<tbody>
<tr>
<td>800</td>
</tr>
<tr>
<td>1000</td>
</tr>
<tr>
<td>1200</td>
</tr>
<tr>
<td>1400</td>
</tr>
<tr>
<td>1600</td>
</tr>
</tbody>
</table>

- Manual Control
- User Activated
- Auto Activated
Evidence of operator dependence on automation

Removing automation
Summary of Findings

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

• Standardized training is not equally effective for everyone
  ▪ Skill acquisition
  ▪ Transfer of training
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?
Results:
Initial Performance
Results:
Initial Performance

Low $g < \text{High } g$
Results: Initial Performance

Automation improves initial performance for learners with lower $g$
Results:
Initial Performance

Not really so for learners with higher g
Results:
End of Training
Results:
End of Training

Low $g < \text{High } g$
Results: End of Training

Reduced effect of $g$ for user activated automation
Conclusions

*If the system inherently includes automation*

- Automation present in training can produce superior performance earlier in practice
- But it may mask differences between operators

*If automation is only being used as a training aid*

- Later removal automation can harm performance
- Better to employ user-initiated automation
Study 2

• Central issue: Should automation vary or reduce across training?
Method

3 conditions

• Manual Control
  ▪ No automation

• Varying selection of automation
  ▪ Part-task training, different subsystems controlled by automation

• Decreasing automation
  ▪ Operator adopts greater control with increasing experience
Method

• Two sessions of training
  ▪ 10 trials per session for 2 days
Design:
Subsystems Automatically Controlled

<table>
<thead>
<tr>
<th></th>
<th>Block 1</th>
<th>Block 2</th>
<th>Block 3</th>
<th>Block 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual control</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Varying automation</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>None</td>
</tr>
<tr>
<td>Decreasing automation</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>None</td>
</tr>
</tbody>
</table>
Learning Principles

• Specificity of training
  vs.
• Variability of practice
Results:
Across Training

![Graph showing the comparison of Units of Good Juice across Block for Manual Control, Varying Automation, and Decreasing Automation. The graph illustrates the performance change over different blocks.]
Results: Across Training

Manual control similar to Study 1
Results: Across Training

Observation of automation only
Results: Across Training

Observation less effective than part-task training (random auto > decreasing auto)
Results: Across Training

Automation that changes is less effective training than Manual Control
Results: Across Training

Part-task training less effective (manual control > varying auto)
Results: Across Training

Some hint that same true for decreasing automation
Aptitude

• Preliminary analyses of individual differences effects
Results:
Initial Performance

![Graph showing Initial Performance comparison between Manual Control and Varying Automation. The x-axis represents Low and High conditions, and the y-axis represents Day 1 Block 1 Performance.]
Results:
Initial Performance

NOTE: No decreasing automation group (no ability to control production initially)
Results: Initial Performance

Automation improves performance for low $g$ learners...
Results: Initial Performance

Automation improves performance for low g learners…

To a greater extent than for high g learners

Initial Performance

To a greater extent than for high g learners
Results:
End of Training
Conclusions

• In initial learning, observation of automation has less benefit than even controlling just one part of the system

• Early in training, limiting control to only individual subsystems improves performance
  ▪ Automation is especially beneficial for low aptitude (low g) learners

• However, as training progresses, using variations of automation and limited control is less effective for learning
Study 3

• Central issue: If automation offers advice (rather than controlling things), does that help?

Conducted in collaboration with undergraduate Glenn Oppegard of Metro State University (Denver), in program partly funded by DoD ASSURE
Method

• 5 conditions
  ▪ Different types and timings of advice
• One brief session of training
  ▪ 4 trials
• Final test without automation
Advice

I. No advice
   • Trial and error learning only
II. Upfront instruction

• Prior to beginning the task, participants shown 7 common scenarios
III. Integrated temporal direct advice

- When system enters relevant state, advice tells them what to do

“Decrease feedstock pump rate”
IV. Integrated temporal explanatory advice

• When system enters relevant state, advice tells them what to do and why

1. “WARNING: The vat is running low. If it empties, the factory will shut down…”
2. “The Feedstock Pump controls the rate of juice taken from the vat, reduce the Feedstock Pump Rate to less than the input Rate…”
3. “To decrease the Feedstock Pump Rate (0-100), type in a number smaller than the current rate into the box and click MANUAL FP.”
V. Integrated temporal & spatial explanatory advice

• When system enters relevant state, advice shows them the relevant item, tells them what to do and why
WARNING: The vat is running low. If it empties, the factory will shut down...
Results:
Transfer (advice removed)
Results:

Transfer (advice removed)

Prior instruction outperforms advice that distracts you from the system.

No advice

Upfront instruction

Direct advice

Explanatory advice

Spatial explanatory advice
Overall CSU Progress

• Completed two large-scale individual differences study
  ▪ Exactly on schedule
• Begun looking at other issues
Future Work

• Further analyses of the two studies
  ▪ Impact of automation on mental models of operators
    • How they conceptualize the system

• Just received “UAV Synthetic Task Environment” from Kevin Gluck at AFRL
  ▪ Use it (or develop a simplified platform from it) to look at the same automation questions
Future Work

• Generating an experiment to look at team performance
  ▪ Impact of training on the knowledge that can be conveyed
  ▪ Basic issue:
    Not just what you do,
    But what you can tell other people about what to do