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Review of Training Principles for Flight Training in Aircraft or Simulator

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Training Principles for Flight Training in Simulator or Aircraft
Overview

• Motivation & Need
• Training Tasks & Desired Outcomes
• Framework of Cognitive Load
• Automation Utilization in Flight Training
• Decision Making in Flight Training
• Implications & Conclusion
Motivation & Need

• Personal Background
  – Flight Instruction & Research
    • Development of Judgment and Decision Making Skills
  – Educational Research
    • Learning from Simulation
Motivation & Need

- Identified Needs
  - Risk of Disconnect Between Research and Practice
    - Particularly in human-performance-driven fields (e.g., Social & Behavioral Sciences)
    - Highly dynamic developments in research and technology
    - Limited/Slow impact on policy- and rule-making
    - Inconsistent/reluctant utilization in practice

  - Flight Training Specifics
    - Master and apprentice relationship
    - Less immediate influence & slower change

  - Applicability
    - Cognitive and behavioral findings at the core of human nature (universally applicable)
Training Tasks & Desired Outcomes

• Overview

Two Main Categories of Learning Tasks in Flight Training:

– Cognitive Tasks
  • Conscious demand on working memory
  • Memorization and problem-solving
    (more details to follow later)

– Perceptual-Motor Tasks
  • Exacting manipulative motor skills
  • Coordinate precise control inputs

(Wong, Marcus, et al. 2009)

(So, 2014)
Training Tasks & Desired Outcomes

- **Overview**

  Desired Learning Outcomes of Training

  - **Acquisition**
    - Knowledge & skills
    - Efficiency measure
    - Goal: Minimize time and effort required to learn new tasks

  - **Retention**
    - Durability – How much of the acquired is retained for future use
    - Goal: Maximize durability

  - **Transfer**
    - Generalizability – How specific training can be used in new contexts
    - Particularly important for flight simulation – Goal: Maximize transfer sim to aircraft

(Healy, Kole, & Bourne, 2014; Healy, Wohldmann, & Bourne, 2005)
Training Tasks & Desired Outcomes

- Influence of Task Type & Information Type

  Conventional Theory & Research

  - Link Between Type of Training Task and Desired Outcomes:
    - Cognitive tasks $\rightarrow$ greater generalizability
    - Motor tasks $\rightarrow$ better retention but less transfer

  (Lohse & Healy, 2012; So, 2014)

- Example Training Principle: Specificity of Training
  - Proportionality between transfer of training and similarity of events
  - Rooted in Identical Elements Theory

  (Thorndike, 1903, as cited in Lohse & Healy, 2012; So, 2014)
Training Tasks & Desired Outcomes

• Influence of Task Type & Information Type

Recent Findings
– Type of Training Task Less Influential Than Type of Information Available/Required During Learning
   (Healy, Wohldmann, et al. 2005; Lohse & Healy, 2012; So, 2014)
– Types of Information:
  • Declarative -> knowing facts
  • Procedural -> knowing how to
   (Ryle, 1949, as cited in Lohse & Healy, 2012)

– Application: Procedural Reinstatement Principle
  • Procedural knowledge’s memory representation closely associated with circumstances of acquisition
    (Crutcher & Healy, 1989; Kolers & Roediger, 1984; McNamara & Healy, 1995)
  • Hence, greater retention than declarative knowledge
  • Extension: Procedural knowledge less generalizable
   (Healy, Wohldmann, et al., 2005; Lohse & Healy, 2012)
Training Tasks & Desired Outcomes

- Influence of Task Type and Information Type – So What?
Training Tasks & Desired Outcomes

- Influence of Task Type and Information Type – So What?

  - Constant Mix of Information in Flight Training Tasks

    Example: Emergency Procedures

    - Combination of system knowledge, checklist steps, and hands-on applications
    - Verbalization of specific procedural knowledge to increase generalizability
    - Stand-Ups in military pilot training

  - Can be similarly applied in the simulator

(Koglbauer, 2016)
Training Tasks & Desired Outcomes

• Influence of Task Type and Information Type –

  So What?

  – Highlights Compromise Between Desired Learning Outcomes

  • Training methods and conditions favorable for one outcome (acquisition, retention, or transfer) may not necessarily benefit another

  • Tradeoffs inevitable

(Healy, Kole, et al., 2014; Lohse & Healy, 2012)
Training Tasks & Desired Outcomes

• Example Training Principles - Advantages and Drawbacks

  – Variability of Practice ->  
    - Increases retention and transferability
    - Decreases training efficiency
    - Variability has to remain within the same program to transfer

  – Strategic use of Scheduling ->  
    - Blocked practice for better acquisition
    - Mixed practice for better retention & transfer
    - Rest intervals important for motor skills training retention (i.e., testing after delay)
    - Periodic refresher training beneficial to retention

  – Strategic use of Feedback ->  
    - Trial by trial feedback good in the beginning; distracting later on

(Healy, Kole, et al., 2014; So, 2014; Wickens, Hutchins, Carolan, & Cuming, 2011)
Training Tasks & Desired Outcomes

• Example Training Principles - Advantages and Drawbacks
  - Strategic use of Difficulty ->
    - Training Wheels and Errorless Learning good for novice, less beneficial to experienced learners during acquisition
    - Cognitive complications beneficial to retention and transfer
    - Also good during prolonged/routine tasks
    - Complications need to be task-relevant

(Healy, Kole, et al., 2014; So, 2014; Wickens, Hutchins, Carolan, & Cuming, 2011)
Training Tasks & Desired Outcomes

• Example Training Principles - Advantages and Drawbacks
  – Strategic use of Knowledge ->
    - Building on existing knowledge increases retention but slows acquisition
    - New training just beyond previous limits (within ZPD) enhances acquisition efficiency
    - Generation Effect & increased depth of processing helps retention (mainly for factual knowledge)
    - Seeding Knowledge & Discovery of Rules increases generalizability

(Healy, Kole, et al., 2014; So, 2014; Wickens, Hutchins, Carolan, & Cuming, 2011)
Training Tasks & Desired Outcomes

• Example Training Principles - Advantages and Drawbacks
  – Strategic use of Complexity  -->  - Part-Task Training beneficial (especially to later transferability to whole-task) if segmented
    - Negative effect for fractionated part-tasks
    (Time-sharing skill requirement not trained)
  – Mental vs Physical Practice  -->  - Mental practice superior for generalizability (e.g., if training and test are dissimilar)
    - Example: Chair-Flying

(Healy, Kole, et al., 2014; So, 2014; Wickens, Hutchins, Carolan, & Cuming, 2011)
Cognitive Load Theory

• Quick Overview
  – Concerned with demand on working memory
  – Considers only conscious mental efforts (biologically secondary knowledge)
  – Working memory limited capacity
  – Demand on working memory in three forms of Cognitive Load:
    • Intrinsic Cognitive Load -> inherent to the task
    • Extraneous Cognitive Load -> circumstantial
    • Germaine Cognitive Load -> required for access to long-term memory (upload) via schemata creation and automation of problem-solving processes
  – Schemata: Cognitive constructs that allow organizing information in a use-dependent framework for storage in the long-term memory

(Wong, Leahy, Marcus, & Sweller, 2012; Wong, Marcus, et al., 2009)
Cognitive Load Theory

• General Application to Training Principles
  – Acquisition benefits from management of Cognitive Load through
    • Reduction of Extraneous Cognitive Load
    • Proper management of Intrinsic Cognitive Load
    • Freeing of resources for Germaine Cognitive Load
  • Examples:
    – Training Wheels and Errorless Learning
    – Reducing Distraction (e.g., too much feedback)
    – Scaffolding Training
  • Effects greater for novice than expert
Cognitive Load Theory

• General Application to Training Principles
  – Retention & Transfer benefits from creation of robust and persistent schemata
  • Through abstract memory representations across multiple different experiences
  • Examples:
    – Variability of Practice (as long as within the same use-schema)
    – Introduction of Cognitive Complications (again, need to be task-relevant)
    – Generation Effect
    – Seeding Knowledge & Discovery of Rules
    – Mental Chair-Flying and “What-if” considerations in Scenario-Based Training

(FAA/Industry Training Standards [FITS], 2007)
Interesting Side-Note:

- Evolutionary adaptations of the working memory
  - In general, higher Cognitive Load when processing information from visualizations (e.g., video) may impair learning outcomes
  - However, motor-specific visualizations seem less effected
  - Thus, observational learning (e.g., a demo in the simulator) may benefit the most if aimed at movement-specific tasks

(Wong, Leahy, Marcus, & Sweller, 2012; Wong, Marcus, et al., 2009)
Automation Utilization in Flight Training

• Generation Effect
  – Significantly lower retrieval performance for knowledge acquired with help of an external agent (e.g., a calculator) vs. the mental self-generation of answers
  
  (Crutcher & Healy, 1989; Jacoby, 1978; McNamara & Healy, 1995; Slamecka & Graf, 1978)

  – Already mentioned: Self-generation more persistent memory representation which supports durability

  – However, automation/external retrieval seems to be favored by the brain due to Cognitive Economics:
    • unconscious selection of cognitive strategies
    • based on automatic efficiency evaluations
    • similar to RPDM (Moffat & Medhurst, 2008) based on previous experiences
    • drive to cognitive resourcefulness
    • exploits any opportunity to reduce Cognitive Load

  i.e., our selfish brains make us addicts of automation

(Pyne & LeFevre, 2011)
Automation Utilization in Flight Training

• Possible Solution
  – Same cognitive resourcefulness supports memorization in the absence of external retrieval agents (due to time and resource advantage over re-generation of answers)
  – Same mechanism seems to get triggered already by attempts to recall information (due to required memory access)
  – Thus, a learning strategy that requires students to first manually attempt solutions before utilizing automation may have similar learning benefits as complete self-generation strategies

  – Broad applicability to flight and simulator training:
    • With use of technology-enhanced flight planning
    • During in-flight work in technologically advanced cockpits

(Pyke & LeFevre, 2011)
**Decision Making in Flight Training**

- Classical view of systematic decision making:
  - Conscious and deliberate rational analysis of alternatives

- However, most decisions in the cockpit less conscious and deliberate:
  - Heuristic Decision Processes
    - Simple rules to follow
    - e.g., Gaze Heuristics: Line-of-Sight picture for a rejoin
  - Rapid Recognition-Primed Decision Making (RPDM)
    - Founded in Intuitive/Naturalistic Decision Making (Klein, 1999, 2004)
    - Decisions under pressure (e.g., limited time, too many unknown, high-risk outcomes, etc.)
    - Recognition-based process building on previous experiences and exposures (Moffat & Medhurst, 2008)
    - Closely resembles the use of schemata as previously discussed
Decision Making in Flight Training

Requirements for Training

• Especially for RPDM to develop
  – Accumulation of sufficient amount of experiences required
  – Situation-based exposure and What-if scenarios
  – Same fundamental processes as for schema creation and associated effects on retention and transfer:
    • Abstraction through discovery of rules
    • Associations of usefulness through variability of training
    • Scenario-Based Training

i.e., what is helpful for generalizability of training seems also beneficial to the development of decision making skills
Implications

• Need for Task-Oriented, Outcome-Specific Approach
  – In learning and training design and application
  – Careful analysis of involved tasks and desired outcomes
  – Hierarchical Task Analysis as one tool

(Wickens, Hutchins, et al., 2011; Wickens, Sebok, Li, Sarter, & Gacy, 2015; So, 2014)

• Include Cognitive and Behavioral Outcomes
  – Behavioral Outcomes to be Included
    • e.g., development of decision making skills
  – DLO & appropriate training principle; e.g.:
    • visualization -> increase in cognitive load
    • Desktop trainer example for task-appropriate simulation
Specifically for Simulation Systems

- Proper Task-Technology Fit in design and application
- Task- and training-objective-specific approach to simulator fidelity evaluation
  - Absolute vs Relative Perceptivity
  - Affordance-based approaches
- Practitioner involvement & development

(Meyer, Wong, Timson, Perfect, & White, 2012)
(Losa, Frendo, Cofrancesco, & Bartolozzi, 2013)
(Grechkin, Plumert, & Kearney, 2014)
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