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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
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, Wohidmann, & 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 -> greater generalizability
• Motor tasks -> better retention but less transfer

(Thorndike, 1903, as cited in Lohse & Healy, 2012)

• Example Training Principle: Specificity of Training

  – Proportionality between transfer of training and similarity of events
    (So, 2014)
  – Rooted in Identical Elements Theory

(Thorndike, 1903, as cited in Lohse & Healy, 2012)
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

  – Types of Information:
    • Declarative -> knowing facts
    • Procedural -> knowing how to

  – Application: Procedural Reinstatement Principle

    • Procedural knowledge’s memory representation closely associated with circumstances of acquisition
    • Hence, greater retention than declarative knowledge
    • Extension: Procedural knowledge less generalizable
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

(Koglbauser, 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)
• 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
  - 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)
  - 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 Germane Cognitive Load
    
    • Examples:
      
      – Training Wheels and Errorless Learning
      – Reducing Distraction (e.g., too much feedback)
      – Scaffolding Training
    
    • Effects greater for novice than expert
• 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
    (Pyke & 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
Implications

• 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)
References


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