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Review of Training Principles for Flight Training in Aircraft or Simulator

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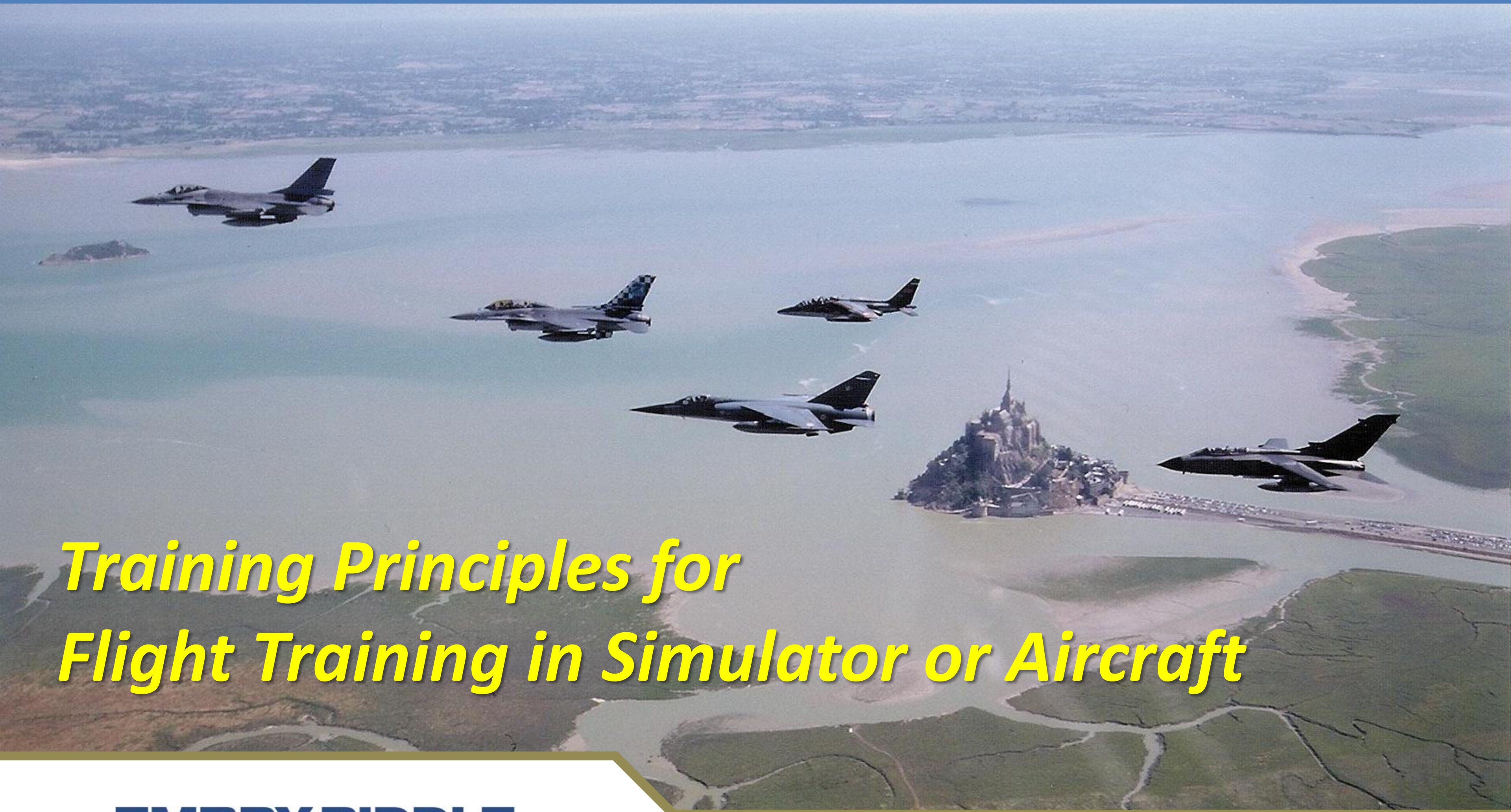
Review



Training Principles for Flight Training in Simulator or Aircraft

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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)

(Wong, Marcus, et al. 2009)

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

(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 -> greater generalizability**
    - **Motor tasks -> 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** (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** (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**

    (Healy, Fendrich, et al., 1992, as cited in Healy, Wohldmann, et al., 2005 and Lohse & Healy, 2012)

    - **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
    - Germane 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

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)

Cognitive Load Theory

- **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: (Pyke & LeFevre, 2011)
    - 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

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

(Pyke & LeFevre, 2011)

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

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 (Gigerenzer, 2017)
  - 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** (Meyer, Wong, Timson, Perfect, & White, 2012)
    - **Absolute vs Relative Perceptivity** (Losa, Frendo, Cofrancesco, & Bartolozzi, 2013)
    - **Affordance-based approaches** (Grechkin, Plumert, & Kearney, 2014)
  - **Practitioner involvement & development**

References

Crutcher, R. J., & Healy, A. F. (1989). Cognitive Operations and the Generation Effect. *Journal of Experimental Psychology: Learning, Memory and Cognition, 15*(4), 669-675.

FAA/Industry Training Standards (FITS). (2007). *Evaluating the effectiveness of scenario based training in the collegiate flight training environment* (Final Report, Joint Training Standards Development for New Technology General Aviation Aircraft, Task 4, FY 2004 FITS Grant, Second Follow-on). Retrieved from https://www.faa.gov/training_testing/training/fits/research/media/SBT_final.pdf

Gigerenzer, G. (2017*). TEDxTalks. How do smart people make smart decisions?.* [Video File]. Available from: https://youtu.be/-Lg7G8TMe_A

Grechkin, T. Y., Plumert, J. M., & Kearney, J. K. (2014). Dynamic affordances in embodied interactive systems: The role of display and mode of locomotion. *IEEE Transactions on Visualization & Computer Graphics, 20*(4), 596-605. doi:10.1109/TVCG.2014.18

Healy, A. F., Kole, J. A., & Bourne, L. J. (2014). Training principles to advance expertise. *Frontiers in Psychology, 5*, 1-4. doi:10.3389/fpsyg.2014.00131

Healy, A. F., Wohldmann, E. L., & Bourne, L. J. (2005). The procedural reinstatement principle: Studies on training, retention, and transfer. In A. F. Healy (Ed.), *Experimental cognitive psychology and its applications* (pp. 59-71). doi:10.1037/10895-005

Jacoby, L. L. (1978). On interpreting the effects of repetition: Solving a problem versus remembering a solution. *Journal of Verbal Learning and Verbal Behavior, 17*, 649-667.

Klein, G. (1999). *Sources of power: how people make decisions.* Cambridge, MA: MIT Press

Klein, G. (2004). *The power of intuition* (paperback edition). New York, NY: Currency

Koglbauer, I. (2016). Simulator training improves pilots' procedural memory and generalization of behavior in critical flight situations. *Cognitie, Creier, Comportament/Cognition, Brain, Behavior, 20*(5), 357-366.

Kolers, P. A., & Roediger, H. L., III. (1984). Procedures of mind. *Journal of Verbal Learning and Verbal Behavior, 23*, 425-449.

Lohse, K. R., & Healy, A. F. (2012). Exploring the contributions of declarative and procedural information to training: A test of the procedural reinstatement principle. *Journal of Applied Research in Memory and Cognition, 1*, 65-72. doi:10.1016/j.jarmac.2012.02.002

Losa, M., Frendo, F., Cofrancesco, A., & Bartolozzi, R. (2013). A procedure for validating fixed-base driving simulators. *Transport, 28*(4), 420-430. doi:10.3846/16484142.2013.867281

McNamara, D. S., & Healy, A. F. (1995). A procedural explanation of the generation effect: The use of an operand retrieval strategy for multiplication and addition problems. *Journal of Memory and Language, 34*(3), 399-416. doi:10.1006/jmla.1995.1018

Meyer, G. F., Wong, L. T., Timson, E., Perfect, P., & White, M. D. (2012). Objective fidelity evaluation in multisensory virtual environments: Auditory cue fidelity in flight simulation. *PLoS One, 7*(9): e44381. doi:10.1371/journal.pone.0044381

Moffat, J., & Medhurst, J. (2009). Modelling of human decision-making in simulation models of conflict using experimental gaming. *European Journal of Operational Research, 196*, 1147-1157. doi:10.1016/j.ejor.2008.05.003

Pyke, A. A., & LeFevre, J. (2011). Calculator use need not undermine direct-access ability: The roles of retrieval, calculation, and calculator use in the acquisition of arithmetic facts. *Journal of Educational Psychology, 103*(3), 607-616. doi:10.1037/a0023291

Slamecka, N. J., & Graf, P. (1978). The generation effect: Delineation of a phenomenon. *Journal of Experimental Psychology: Human Learning and Memory, 4*(6), 592-604. doi:10.1037/0278-7393.4.6.592

So, C. Y. (2014). *Acquisition, retention and transfer of heavy equipment operator skills through simulator training* (Doctoral Dissertation, Purdue University) Available from ProQuest Dissertations & Theses Global. (UMI No. 3702100)

Wickens, C., Hutchins, S., Carolan, T., & Cumming, J. (2011). Investigating the impact of training on transfer: a meta-analytic approach. *Proceedings of the Human Factors and Ergonomics Society 55th Annual Meeting, 2011*, 2138-2142. doi:10.1177/1071181311551446

Wickens, C. D., Sebok, A., Li, H., Sarter, N., & Gacy, A. M. (2015). Using modeling and simulation to predict operator performance and automation-induced complacency with robotic automation. *Human Factors, 57*(6), 959-975. doi:10.1177/0018720814566454

Wong, A., Leahy, W., Marcus, N., & Sweller, J. (2012). Cognitive load theory, the transient information effect and e-learning. *Learning and Instruction, 22*, 449-457. doi:10.1016/j.learninstruc.2012.05.004

Wong, A., Marcus, N., Ayres, P., Smith, L., Copper, G.A., Paas, F., & Sweller, J. (2009). Instructional animations can be superior to statics when learning human motor skills. *Computers in Human Behavior, 25*, 339-347. doi:10.1016/j.chb.2008.12.012

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Questions?

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