Performance and Training

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Outline

- Ability versus skill
- What to train
- How to train
- Assessment: performance metrics
- Validation

Ability Versus Skill

- Ability (capability or aptitude):
  Ability…refers to a hypothetical construct that underlies (or supports) performance in a number of tasks or activities. An ability is usually thought to be a relatively stable characteristic or trait. [Schmidt & Lee, 1999]
- Skill:
  – *Skills are learned or trained*
  – *Skill implies some coordinated physical or cognitive activity to achieve a goal*
  – *Skill implies flexible or adaptive performance*
  [Patrick, 1992]

Ability: Fleishman's Taxonomy of Component Abilities

- Cognitive abilities
  e.g., deductive and inductive reasoning, spatial orientation and visualization, selective attention
- Psychomotor abilities
  e.g., control precision, reaction time, finger dexterity
- Physical abilities
  e.g., strength, flexibility, coordination, stamina
- Sensory/perceptual abilities
  e.g., visual acuity, color discrimination, depth perception

Skills: Gagne's Learning Outcomes

- Intellectual skills ("knowing that")
- Verbal information ("knowing how")
- Cognitive strategies
- Motor skills
- Attitudes

Analyzing Skills: Task Analysis

- Hierarchical task analysis (Cao et al., 1999)
- Task and motion studies (Cao et al., 1996)
- Critical incident technique
- Major limitation: difficult to analyze *implicit* (non-verbalizable) skills, such as spatial or perceptual-motor

Example of Hierarchy: Laparoscopic Cholecystectomy

- Prepare patient
- Isolate gallbladder
  - Locate visually
  - Grasp & elevate
    - Poke
    - Tease
  - Dissect surround
    - Poke
    - Tease
    - Cut
    - Cauterize
- Remove gallbladder
- Close

Rasmussen's Cognitive Hierarchy

- Skill-based level:

  "sensory-motor skill"

  "...continuous control of the movements required by the interaction with a work environment..."

- Rule-based level:

  "... organization of the routine patterns of movements... into the proper procedural sequences."

- Knowledge-based level:

  "problem solving level"

  "...generation of plans to be used by the sequence controller for new situations."

Reason's Error Modeling System

- Skill-based errors: slips and lapses
  - Often due to inattention
  - Surgery usually robust to slips if caught in time
- Rule-based mistakes
  - E.g., following a rule that is usually correct, but fails in an anomalous situation
  - Bad rules

Reason's Error Modeling System

- Knowledge-based mistakes
  - Similarity matching
  - Frequency gambling
  - Selective attention
  - Confirmation bias
- Appropriate rules can be taught to reduce the likelihood of knowledge-based errors

Example: Bile Duct Injury During Laparoscopic Cholecystectomy

Critical Steps in Laparoscopic Cholecystectomy

- Use lateral traction on the infundibulum of the gallbladder during dissection
- Dissect the space between the gallbladder and cystic duct completely
- Clear the triangle of Calot enough to show the hepatic side of the infundibulum
- Use an angled scope to gain proper view of the triangle of Calot
- If the duct won't fit entirely within a 9mm clip, assume it is the common duct
- Any duct that look as if it goes behind the duodenum has to be the common duct

Issues in Training: Part- versus whole-task training

- Whole task best when interrelationship between task elements is complex
- Part task best when individual elements are difficult, but task organization straightforward

Issues in Training: Guidance

- Provided during task performance
- Various forms
  - Verbal guidance (advice)
  - Visual guidance (demonstration)
  - Physical guidance (haptic guidance)
  - Cueing

Issues in Training: Augmented Feedback

- Knowledge of results: feedback of outcome
  - E.g., “you took 7 minutes,” “you nicked the liver 3 times.”
- Knowledge of performance
  - E.g., “you used 30% too much force,” “you dragged the needle instead of driving a smooth arc.”
  - Difficult to measure objectively conventionally, but may be possible with measures feasible in simulation

Recognizing and Classifying User Behavior

- Sequence of position and/or force states: hidden Markov models
  - Rosen et al., 2001
  - Trochim et al., 2001
- Dynamic behavior recognition
  - Tendick et al., unpublished

Performance Metrics: Declarative Knowledge

- Declarative knowledge is explicit knowledge of facts, e.g.:
  - Anatomic landmarks
  - Indications and contraindications for a procedure
  - Physiological effects of surgical interventions
  - etc.
- Assessed via quiz or recognition tasks

Performance Metrics: Procedural Knowledge

- Explicit knowledge of how to perform a procedure, e.g.:
  - Sequence of navigation of anatomic landmarks
  - Steps of a surgical intervention
  - Proper use of surgical instrument (e.g., “see both tips of a surgical clip applier before securing clip”)
  - Dealing with unusual situations
    - » Like losing an engine in flight simulation
    - » Difficult anatomy in laparoscopic cholecystectomy
- Can be expressed verbally, but may depend on non-verbal (e.g., visual or haptic) information
- Traditionally tested verbally, but can be assessed in simulation using realistic environment

Performance Metrics: Implicit Knowledge

- Difficult or impossible to verbalize, e.g.:
  - Visual recognition of anatomic features
  - Performance of a perceptual-motor skill
  - Tactile recognition of tissue condition
  - Integration of spatial information from one or more imaging modalities, e.g. ultrasound, endoscope, etc.

Performance Metrics: Perceptual Skills

- Examples:
  - Recognition: what is this?
  - Accuracy: which of these images is correct?
  - Identification: is this diseased or healthy?
  - Navigation: find this landmark
- Can be assessed in "realistic" situation in simulation, with limited information possible, e.g. in minimally invasive surgery
- Augmented knowledge of performance possible, e.g. with "bird's eye" view of endoscope location

Performance Metrics: Perceptual-Motor Skills

- Examples:
  - Guidance of an endoscope in the colon
  - Simple laparoscopic motor skills: two-handed manipulation
  - Complex laparoscopic motor skills: suturing and knot tying
  - Exposure: planning integrated action of scope, assisting instruments, and surgeon's action to create and maintain access to operating space
- Knowledge of performance possible with behavior recognition
- Guidance possible with augmented visual and haptic information

Performance Metrics: Perceptual-Motor Metrics

- Time
  - But the fastest surgeon is not necessarily the best!
- Accuracy
  - Position
  - Trajectory
  - Unintended contact
  - Force
- Task-based criteria
  - Successful result
  - Avoidance of undesired events

Validation

- Reliability
  - Test - retest
  - Internal consistency within test
- Content validity
  - Are the measures tested within the simulation appropriate to the task to be trained, e.g. as determined by a task analysis

Validation

- Construct validity
  - Does the test measure the quality it's supposed to?
  - E.g., does an expert surgeon perform better in the simulation than a novice?
  - Many demonstrations of construct validity for research and commercial simulations

Validation

- Concurrent validity
  - Does performance in the simulation correlate with performance in the real environment?
- Predictive validity
  - Can performance in the simulation predict future performance in the real environment?
  - Pre-assessment: can you predict whether a medical student could become a successful surgeon?

Validation

- Training transfer
  - This is what's really important
  - Does training in a simulation improve performance in the real environment?
  - Very few published studies so far testing transfer from surgical simulations

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