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]

Skills: Gagne’s Learning Outcomes

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

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

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
    - Tare
  - Dissect around
    - 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

- 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

- 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 looks as if it goes behind the duodenum has to be the common duct

Critical Steps in Laparoscopic Cholecystectomy
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.
- 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?

References: Fundamentals


References: Research