Acquisition of Cognitive Skill

Cognitive skill versus what?
- All skill involves cognition. “cognitive skills could be distinguished by saying that they are primarily cognitive” p. 358.
- Role of motor behavior in cognitive skill is that “it expresses the cognitive skill” p. 358.
- Example of manuscript text-editing, includes the skills of keystroking and viewing the manuscript and display; however, these perceptual-motor skills are not the essential activity, but the medium through which the cognitive activity gains expression” p. 358.

Cognitive Skill versus Problem Solving
- Skill dimension runs from “problem solving” to “cognitive skill.”
- “problem-solving behavior is simply the less skilled end of this dimension; it is not a separate species of behavior nor a separate class of tasks” pp. 360-361.

The Problem Space Hypothesis
- Problem-solving takes place by search in a problem space with partial knowledge of how to proceed, the search control knowledge, being used to guide the search through the space.
- “The difficulty of performance in a problem space can be graded by how much the search control knowledge available in the problem space constrains behavior.”

Search Control Knowledge
- W/little SCK much trial and error. W/much SCK “behavior proceed directly from the initial point in the PS to the final goal state w/only occasional error.”
- “For behavior from the skilled end of the dimension, the sequence of operators performed are highly predictable from the structure of the task” p. 362.

The Power Law of Practice
- “Applies uniformly to all types of cognitive behavior, so long as the behavior is sufficiently well organized to attain the task. The law applies not only to skilled behaviors (cognitive and perceptual-motor), but also to problem-solving behaviors.”
log-log examples

- cigars
- Koler's inverted reading
- Asimov's writing of books
The Curious Incident of the Dog in the Night-time

or after 4 months and 78,240 trials where is the learning?

The Curious Incident (2)

“Is there any point to which you would wish to draw my attention?”

“To the curious incident of the dog in the night-time.”

“The dog did nothing in the night-time.”

“That was the curious incident,” remarked Sherlock Holmes.


The Curious Incident (3)

Focus here on the intriguing absence of evidence for learning over the four month trial. Two tacks.

Do the models predict the monthly fluctuation in the worktime difference between the two workstations?

Use CPM-GOMS to examine some implicitly held assumptions.

The Curious Incident (4)

Why a 6-month trial?

Assuming 800 calls per day

| Day of Trial | Time Block | log |
|--------------|------------|-----|---|
| day 1 - AM  | 10         | 1   | 0|
| day 1 - AM  | 720        | 2   | 0.3010|
| day 2 - AM  | 1000       | 3   | 0.4771|
| day 125     | 100000     | 4   | 8.0477|
| day 1250    | 1000000    | 5   | 12.5292|

125 days would be approximately 6 months (at 240 workdays per year)

1250 days would be 5.2 years

The Curious Incident (5)

Predicting the Fluctuation
The Curious Incident (6)

- Implicitly Held Assumptions.
  - Would Learning have been noticed?
  - LOG-LOG law of learning led us to plan a long trial.
  - But, all our TAOs were already expert in handling calls. For the proposed workstation all they had to do was learn the new keyboard and display layouts and some differences in keying procedures.

The Curious Incident (7)

- The CPM-GOMS critical paths rarely include the movement to the correct keys and never include eye-movements.
- Implication is that most of the learning occurred during the slack time of a call. It is possible that learning occurred after the first month but being in the slack time, it did not decrease worktime.

Cognitive consequences of experience

- Mental models: examples from HAWK Air Defense Radar

Drawing by 1st yr mechanic

Functional drawing by 1st yr mechanic

Functional drawing by 5th yr mechanic
Functional drawing by 10th yr mechanic

Cognitive Skill from Problem Solving

- Definition of a Problem Space
  - A set of knowledge states
  - A set of operators for transforming states into other states
  - A problem within a problem space is defined by an initial state and a goal (a state or set of states)
  - Solving the problem consists of finding a sequence of operators (often called a path) to transform the initial state into a goal state

- Tower of Hanoi

Accumulation of SCK

- "With little [search] control knowledge, the problem solver will wander about the problem space in search of a goal state. But with training or experience in doing the problem, the problem solver will acquire knowledge for guiding the search and making it more efficient." p. 365.
Accumulation of SCK

- As search control knowledge increases, a person becomes more expert, and behavior changes from problem solving to cognitive skill.
- "Thus, problem solving and cognitive skill both take place in a problem space, the main difference being the amount of search control knowledge available" (p. 385).
- Where do GOMS methods come from?
  - It is as though the flexible control structure of problem solving were frozen into specific procedures that are available at performance time.

What Happens when an Error Occurs while Executing a Cognitive Skill?

- "The occurrence of an error throws the user off the path into another state, but one that is still a state in the problem space. He then has to formulate another goal to get back onto the intended path. This goal may be reachable by an available error-correction method; but, if there are no methods available, the user can search for the solution in the problem space." (p. 372).

Acquisition of Operators

- Key notion
  - Search control knowledge accumulates by the acquisition of new operators
  - The new operators reduce the problem space in which problem-solving occurs
  - Leaves us with a
    - Reduced problem space, and a
    - Skill space

- TOH example, learning an operator for moving the two smallest disks
Levels of Cognitive Behavior

- "Complex cognitive behavior is organized into a nested hierarchy of problem spaces."

- "Thus, a complex cognitive behavior is a medley of varying degrees of skill. When we speak of a given degree of skill for a behavior, we are really referring to some sort of average skill over the various levels" p. 373.

The Unit Task

- "The unit task partitions the behavior stream, thus providing the basic structural foundation on which the detailed models can be erected" (p. 385)

- Four aspects of unit tasks are important
  - Well-defined internal structure
  - Control construct for the user
  - Duration of unit tasks
  - Relationship to problem-solving

Internal Structure of Unit Tasks

- A structured cycle of repeated actions.
  - Unit task = acquire + execute
  - Execute = locate + act + (verify)

Unit Tasks Function as a control construct for the user

- "The unit task is fundamentally a control construct, not a task construct" p. 386.
**Durations of Unit Task**

- Acquisition phase of a UT is determined by how well the task is specified and presented to the user.
- Duration of the execution phase is determined by the length of the method used.
- The two phases independently determine the length of the UT.
- Most UTs seem to be in the 30 s range.

**Duration (cont’)**

- "The execution phase of unit tasks averages about 10 sec in all the interaction tasks we have studied (Chapters 5, 8, and 10). Execution can be as short as a second or two (for a one-key command); we have observed only two editing-task executions lasting over 30 sec" p. 390.
- "How long an execution can be depends on how complex a method the user is willing to spend time and effort to assimilate" p. 390.
- "Given the considerable effort needed to assimilate complex methods, it is not surprising that we only observe short and simple methods in human-computer interaction tasks" p. 390-391.

**Relationship of UTs to PS**

- UTs functioning as operators in problem spaces
  - UT = acquire + execute
  - Operator = execute
  - PROBLEM-SOLVING = acquire

**Determinants of UT Structure**

- Unit task structure emerges from three types of constraints on behavior
  - Working memory capacity,
  - Information horizons, and
  - Error control.

**Information Horizons**

- Data Horizons
- Task Horizons
- Method Horizons
Error Control

- Smaller UTs may be desirable to verify each component or to localize errors and limit their effect.