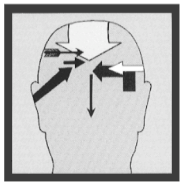
Acquisition of Cognitive Skill



Wk08 Psyc530

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

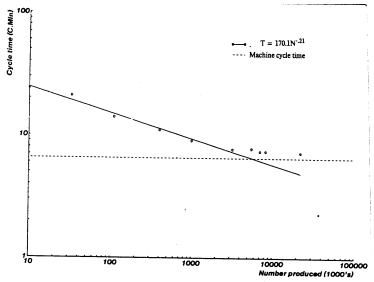


FIG. 1.2. Cross-sectional study of learning in cigar manufacturing (log–log coordinates). Replotted from Crossman (1959).

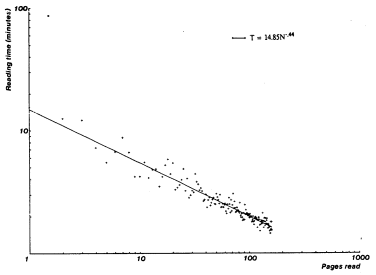


FIG. 1.3. Learning to read inverted text (log–log coordinates). Plotted from the original data for Subject HA (Kolers, 1975).

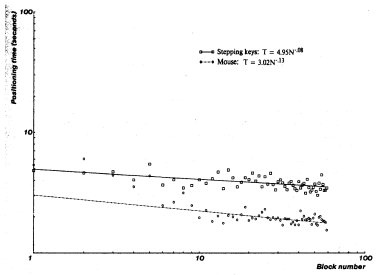


FIG. 1.5. Learning to use cursor positioning devices (log–log coordinates). Plotted from the original data for Subject 14 (Card, English, & Burr, 1978).

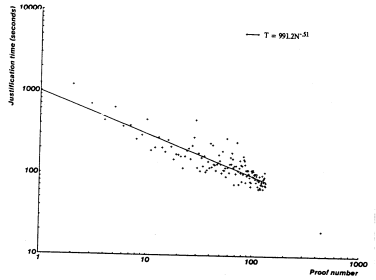
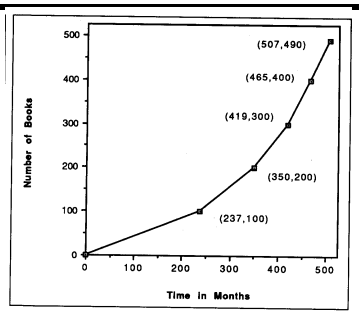


FIG. 1.9. Learning in a geometry proof justification task (log–log coordinates). Plotted from the original data (Neves & Anderson, in press).

Asimov Fig1: The accumulated number of books as a function of time



Asimov Fig2

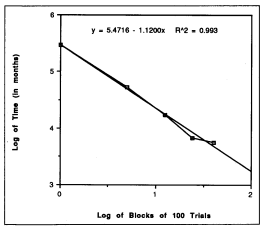
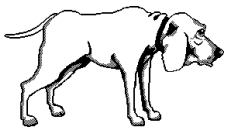


Fig. 2. The time to complete 100 books as a function of practice, plotted with logarithmic coordinates on both axes.

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.

Doyle, A. C. (1986). Silver Blaze. Sherlock Holmes: The complete novels and stories (Vol. 1, pp. 455-477). New York: Bantam Books. (Original work published in 1892)

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)

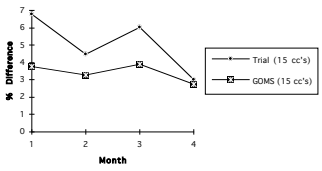
- **Why a 6-month trial?**
  - **Assuming 800 calls per day**

day of trial	# of calls	log
day 1 -- AM	1	0
day 1 -- AM	10	1
day 1 -- AM	100	2
day2 -- AM	1000	3
day 12	10000	4
day 125	100000	5
day 1250*	1000000	6

- **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.**

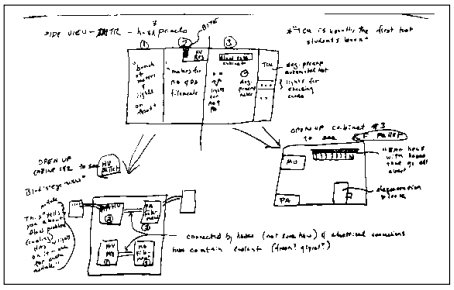
The Curious Incident (7)

- **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.**

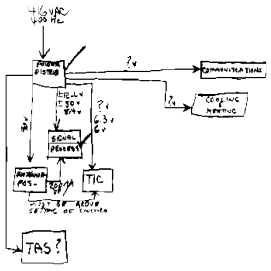
Cognitive consequences of experience

- **Mental models: examples from HAWK Air Defense Radar**

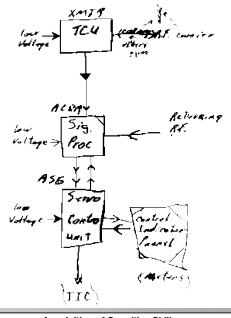
Drawing by 1st yr mechanic



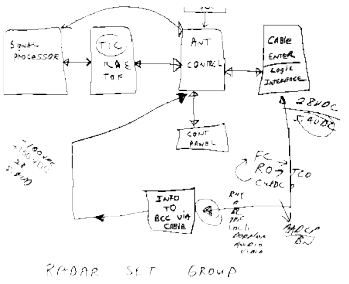
Functional drawing by 1st yr mechanic



Functional drawing by 5th yr mechanic

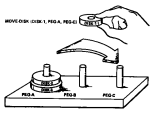


Functional drawing by 10th yr mechanic



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**



Informal Description: Three pegs—labeled PEG-A, PEG-B, PEG-C—are attached to a board as illustrated above. Disks of different diameters—labeled DISK-1 (the smallest), DISK-2, DISK-3, etc.—are stacked on PEG-A in a pyramid. The goal of the puzzle is to move the pyramid of disks to PEG-C by moving the disks from peg to peg, one at a time. A disk may be moved from any peg to another providing that it is the top disk on its peg and that it is not moved on top of a smaller disk.

States: Any configuration of the disks on the pegs such that a larger disk is not on top of a smaller disk.

Operator: MOVE-DISK (Disk, FromPeg, ToPeg) causes Disk to be moved from FromPeg to ToPeg.

Path Constraint: On each MOVE-DISK, Disk must be the top disk on FromPeg and Disk must be smaller than the top disk on ToPeg.

Problem: All disks on PEG-A. ⇒ All disks on PEG-C.

Figure 11.2*a*. Problem space definition for the Tower of Hanoi puzzle.

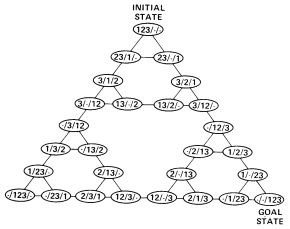


Figure 11.2*b*. Problem space graph for the three-disk Tower of Hanoi puzzle.
Each state is described as "Disks-on-PEG-A / Disks-on-PEG-B / Disks-on-PEG-C." For example, the state 23/1/– indicates that DISK-1 is on PEG-B and DISK-2 and DISK-3 are on PEG-A; this state comes about by applying the operator MOVE-DISK (DISK-1, PEG-A, PEG-B) to the initial state, 123/–/–. Each link in the graph represents an application of the MOVE-DISK operator.

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.

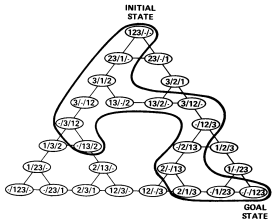


Figure 11.4*a*. Solution path in the Tower of Hanoi problem space for a hypothetical novice.

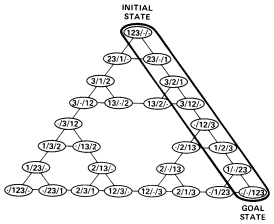


Figure 11.4*b*. Solution path in the Tower of Hanoi problem space for an expert.

369

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. 365.
- 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**

Problem Space that Remains after an Operator is Acquired for Moving the two Smallest Disks (compare with Fig11.2b)

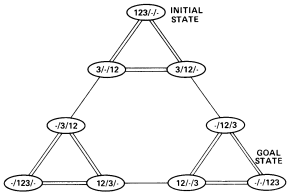


Figure 11.6*a*. Reduced problem space for the three-disk Tower of Hanoi puzzle.
The single-line links represent MOVE-DISK operations, just as in Figure 11.2*b*. The double-line links represent MOVE-DISKS-12 operations.

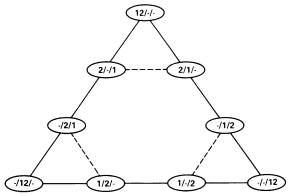


Figure 11.6*b*. Skill space for the two-disk subproblem of the Tower of Hanoi puzzle.
The solid links represent MOVE-DISK operations. The dashed links represent potential MOVE-DISK operations that the user does not perform, since they are not needed in the skill space.

374

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.

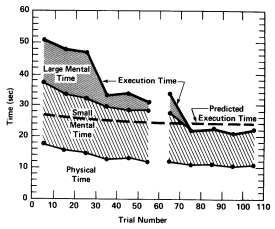


Figure 11.10. User's execution time in the clause-switching task in Experiment 11A.
The times are averaged in 10-trial blocks. The top solid line shows the user's actual execution times; and the dashed line shows the predicted time to execute the user's best method, as calculated with the Keystroke-Level Model. The user's time is decomposed into three components: the physical time (the unshaded area on the bottom), the small mental time (the lightly shaded area in the middle), and the large mental time (the darkly shaded area on the top). See the text for how these time components are defined and interpreted.

The Unit Task

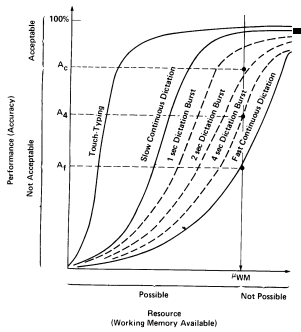
- "The unit task partitions the behavior stream, thus providing the basic structural foundation on which the detailed models can be erected" (p. 385)
- Four aspects of unit tasks are important
  - Well-defined internal structure
  - Control construct for the user
  - Duration of unit tasks
  - Relationship 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.

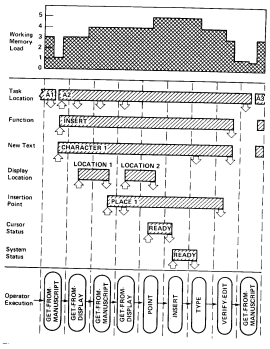
Relationship of UTs to PS

- 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.

Working Memory Capacity



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