Dual Coding Theory: Paivio

Words, Images, Experts

May 31, 2011
INF 143
Images vs Words (Ware, p. 304)

Images good for:
- Showing structural relationships
- Localization of information
- Remembered better
- Conveying detail

Words good for:
- Abstract concepts
- Procedural information (how to do it)
- Program logic
- Conditional information (If ..., then ....)

Labels for Images

- Use Gestalt principles
  - Proximity
  - Similarity (e.g., color)
  - Connectedness
  - Common region
Some Additional Mind Things

- Chunking – organizing material based on knowledge
- Acquiring expertise

Chunking

- Combining single units of information into larger units, based on knowledge stored in long-term memory
- Examples:
  - 1776949143
  - 603742741
- Example: recall of binary digits

Recall of Binary Digits

- Task is to recall random binary digits
  - 101001110101110011
  - very difficult when gets longer than 5-7
- learn binary to octal conversion
  - 101 001 110 101 110 011
  - 5 1 6 5 6 3
- able to remember almost 3x as many binary numbers

Binary to Octal Conversion

- 000 --> 0
- 001 --> 1
- 010 --> 2
- 011 --> 3
- 100 --> 4
- 101 --> 5
- 110 --> 6
- 111 --> 7
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Chunking X-Games

- Undergraduate student
  - Worked on memory span 3-5 days a week
    - 1 hour/session
    - For more than two years
- Memory span task
  - List of random digits
  - 1 digit per second
  - Repeat back immediately
  - If correct, increased length by 1 digit
  - If incorrect, decreased length by 1 digit

Chunking X-Games

- 24+ months of practice
- 250 hours of lab testing
- Increased span from 7 to 80 digits

Chunking X-Games: Technique

- Initial phase
  - Recoded groups of 3-4 digits into running times
  - E.g., 3492, “3 minutes and 49 point 2 seconds, near the world-record time for mile”
  - Later added ages & dates
  - E.g., 893, “89 point 3, very old man”
  - Got last 4-6 digits in rehearsal buffer
  - Able to get memory span to roughly 30 digits
- Later phase
  - Grouped these groups into supergroups
  - E.g., 44, 33
  - By end, 444 444 333 333 444 333 444 5
**Chunking X-Games**

- Did not increase his memory span
- Groupings based on 3s and 4s
  - I.e., groups were not arbitrarily big
- Late in training, switched to letters
  - Span was 6 letters
- His strategy was very specific to numbers

**Remembering Chess Boards**

- Novice vs. Expert
- Meaningful vs. Random Boards
- Expert >> Novice on meaningful boards
- Expert = Novice on random boards
Chunking: Summary

- Using knowledge in LTM to encode information in STM
- Can be developed with practice
- Workaround for limits of STM

Design Implication

- Organize material consistent with what your audience knows → makes it easier to scan and to remember
Stages of Skill Acquisition

- Cognitive -- declarative encoding
  - “Engage clutch. Move stick.”
- Associative -- knowledge compilation
  - “Increase gas as clutch released.”
- Autonomous -- procedural stage
  - Talking to passenger while shifting

Expertise

- Very long-term learning (years)
- Achieving very high levels of performance

Acquisition of Cognitive Skill

- Transition from declarative to procedural knowledge (proceduralization)
- Proceduralization follows the Power Law of Learning
FIGURE 8.11: Improvement with practice in time taken to add two numbers. Data are given separately for two subjects. Both time and problem number are plotted on a logarithmic scale. (Plot by Cramton, 1965, from data in Blackman, 1964.)

FIGURE 9.4: The results for readers in Kohler's reading-skill experiment (1975) on two tests more than a year apart. Subjects were trained with 200 pages of inverted text with occasional pages of normal text intermixed. A year later they were retested with 100 pages of inverted text, again with normal text occasionally interspersed. The results show the effect of practice on the acquisition of the skill. Both reading time and number of pages per minute are plotted on a logarithmic scale. From Kohler, 1975. Copyright by the American Psychological Association. Reprinted by permission.)
Chi, Feltovich & Glaser

- Classic article on the nature of expert-novice differences
- Compare advanced PhD students with beginning students in physics
- Methods
  - problem sorting
  - problem descriptions
  - thinking aloud during problem formulation
- surface vs. deep basis for classifying problems

Experts vs. Novices

- Experts – code problems on the basis of deep physics principles
  - E.g., Newton’s laws of motion
- Novices – code problems on the basis of surface forms
  - E.g., springs, inclined planes
Ericsson Studies of Real Experts

- Analysis of high levels of expertise
- Practice alone is not enough: “deliberate practice” is required
- Skill acquisition occurs forever (Power Law of Practice)

Empirical Studies

- Study 1: How do violin students spend their time?
  - diary & interview studies
  - amount of practice related to their level of achievement
- Study 2: How do pianists spend their time?
  - diary & interview studies
  - amount of practice related to their level of achievement
  - expertise related to component skill performance
Scrabble Experts

- Memorize specialized words
  - All Qs without a u
  - All 3, 4, 5 letter Qs
  - Words with lots of vowels
  - 2-letter words
  - 3-letter words formed from 2-letter words
  - Etc, etc
- Memorize what you can make from 5, 6, 7 letters
  - Organized by alphabetizing letters
  - The ranked by probability of getting in a Scrabble game
- Strategies for maximizing scores
  - Bingos especially sought after
  - Use of bonus squares

Hayes 10-year Idea

- It takes 10 years to achieve master-level performance
- Analyzed music composers
  - Index of mastery: how often a composition has been recorded
  - Peaks at 10 years into career
  - Very different starting points
    - Mozart – started at 6; but 10 years to first major works
Constraints in Achieving Expertise

- **Resource**: access to teachers, facilities
- **Effort**: amount of deliberate practice
- **Motivation**: practice is not fun, therefore have to find the performance at high levels to be a motivating factor
- **Each person can be a world-class expert in a very small number of things**
**Expert-Novice Differences**

- Experts **know more**
- Experts **organize** what they know **differently**
- Experts' knowledge is more likely to be **proceduralized**
  - **Paradox of the Expert**: Less able to explain what they know
- Experts solve problems by moving from **givens to solutions**; novices often solve by working backwards
- It takes a **long time** to become an expert (10-year rule)
  - deliberate practice is the key; innate factors not very important

**Design Implication**

- Know what your audience knows
- Experts and novices (with respect to the domain) will “see” things differently