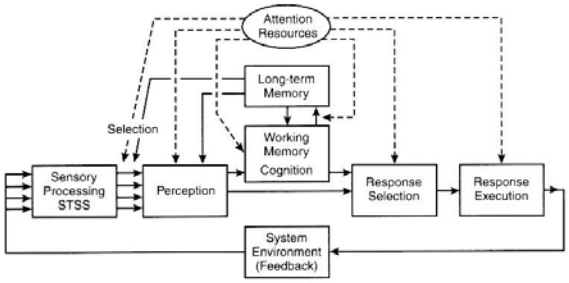
CMPE 233: Human Factors

Cognition

Human Memory



Human Memory

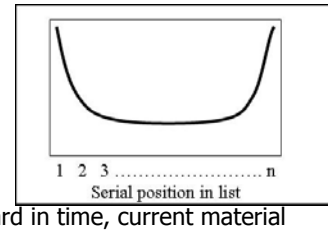
- Three stages → failure in any = memory failure
  - Encoding: operator's extraction of relevant information from the sensory store (attended information) into working memory (WM) and long-term memory (LTM)
  - Storage: types of memory codes (decay?)
  - Retrieval: based on environmental cues, relevant memory traces must be linked to current operator needs and retrieved
- WM vs. LTM → Phenomenological distinction
  - contents of WM occupy consciousness
  - contents of LTM are unconscious unless retrieved into WM
- WM vs. LTM → Behavioral evidence
  - WM: Rapid "decay", limited capacity
  - LTM: Decay? Capacity?

Capacity Limits of Verbal Code in WM

- Miller (1956): 7 +/- 2 items (~3 bits)
- What is an *item*? (features, letters, words, phrases?)
  - an item is defined by its code in LTM: the number of LTM *chunks* required to store an item
  - definition of item depends on operator's task and experience
- Capacity limits are even lower for a *running memory* task, Moray (1980)
- Chunking or *recoding* of information
  - greater than 7+/-2 items can be remembered if items are recoded into a smaller number of larger "chunks"
  - takes advantage of pre-existing knowledge in LTM to increase the capacity of WM
  - associations of items with existing LTM increases probability that a LTM trace will be created

Working Memory

- Temporal Limits (decay)
  - WM decays unless rehearsal is maintained
  - interference is NOT decay
- Types of interference
  - proactive: interference forward in time, current material prevents learning of subsequent material
  - retroactive: interference backward in time, current material prevents learning of previous material
- Interference at work: the serial position effect
  - primacy effect
  - recency effect



WM – Implications for Design

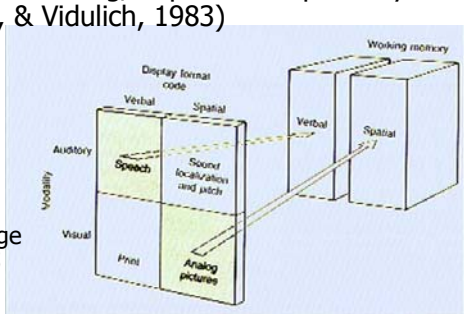
- Training and consistency
  - highly trained experts chunk information more effectively due to robust LTM representations
  - training only helps if environment is consistent with training
  - Chase & Simon (1973): chess masters vs. novices
    - "real" board: masters have better memory
    - random board: no difference in memory
  - Barnett (1989): Verbal communication between pilots and ATC (air-traffic control)
    - normal communications sequence: experts better
    - random communications sequence: no difference

WM – Implications for Design

- Capitalizing on Familiarity
  - make items that need to be remembered easily "chunkable"
  - passwords that form real words or phrases: I82MUCH
  - phone numbers: "1-800-collect"
- Parsing
  - introduce physical discontinuities to enhance chunking
  - e.g., phone numbers, outlining, indentations of program statements in computer programming
- Sequencing Data Output
  - output items less likely to be remembered first
  - unchunked items (e.g., last 4 digits of phone number)
  - items from middle and end of list

Theories of WM & Display

- Dual-code Theory (Paivio, 1986)
  - memory for abstract vs. concrete terms
  - concrete terms are easier to remember due to use of both phonetic and image-based codes
- Stimulus/central processing/response compatibility (Wickens, Sandry, & Vidulich, 1983)
  - Spatial tasks are best served by analog visual displays
  - Verbal tasks are best served by auditory displays, unless the message is longer than 4-5 words



Long-term Memory

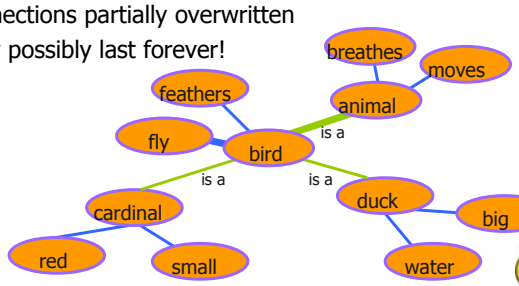
- Declarative: "knowledge of" - encyclopedic
  - easily retrieved and communicated to others (learned)
  - episodic: memory of specific events, e.g., rote learning, analog code
  - semantic: knowledge abstracted from events (the *gist*)
    - based on semantic relationships (meanings) between concepts
    - propositional code -- *Cats have whiskers*
    - Structure: mental models, schemata, scripts
  - sometimes verbatim knowledge is required
    - passwords, codes, names, jokes → mnemonics?

Long-term Memory

- Procedural: "knowledge how"
  - generally involve motor behavior
  - difficult to conceptualize and communicate
  - best learned through rehearsal or practice
  - Structure: procedures or highly automated scripts (skills)
- "Hebbian learning" to strengthen neural links → how neuronal connections are enforced in mammalian brains
  - Simultaneous activation of neural pathways
  - Intermittent coactivation (exposure) most effective

Hebbian Learning

- Link strength
  - Affects ease of access
  - Function of usage frequency
- Lack of use
  - Connections partially overwritten
  - They possibly last forever!



LTM & Training

- Training Efficiency → level of proficiency per dollar of investment
- requires procedures that produce...
  - the greatest rate of learning (quickness of training)
  - the greatest retention (permanency of training)
  - are cheap to implement
- Best training method depends on the type of knowledge you are trying to convey
  - Declarative: study and rehearsal are best
  - Procedural: practice and performing to gain *automaticity*

Training and Feedback

- Feedback: providing knowledge of error
- critical for efficient training
- Practicing errors is detrimental to training
  - difficult to unlearn "bad habits"
  - *guided training*: prevent large errors from occurring so that they can't be learned
  - *off-target feedback*: provide feedback only when errors exceed predefined limits
  - *augmented feedback*: augment training environment to simplify the procedure: e.g., training wheels
- Feedback is most effective if it immediately follows

Rehearsal to Encode Declarative Knowledge

- Rote rehearsal: pure "recycling" of the phonetic code
  - good for maintaining information in WM
  - contributes little to transfer of information into LTM
- Elaborative rehearsal: actively seeking associations between material to be learned and existing knowledge
  - greater focus on visual and semantic codes
  - form associations between known concepts (already stored in LTM) and incoming information
  - much greater transfer of information into LTM than rote rehearsal

Training to Encode Procedural Knowledge

- consistent "practice makes perfect"
  - consistent practice leads to the development of automaticity
- skilled performance continues to improve even after errors are no longer being made
  - speed of performance increases at a rate proportional to the log of the number of practice trials
  - attention and resource demands decline as task becomes more automatic
- learning requires attention
- effective learning cannot take place if
  - extraneous task demands divert attention
  - operator is under high attentional workload (must pay attention to too many things at once)

Reducing Task Complexity in Procedural Training

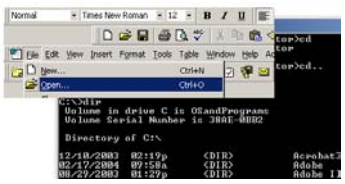
- Tasks that are overly complex are difficult to learn because not enough attention may be directed to each component of the task for effective training
- Adaptive training
  - simplify one component of the complex task to decrease initial level of difficulty
  - as training proceeds, gradually increase complexity until component complexity is normal
  - problem: people will learn strategies during the "simple" phase that may be incompatible with strategies needed in the difficult phase, e.g. shift vs. automatic car

Reducing Task Complexity in Procedural Training

- Part-task training: learn elements of a complex task separately
  - segmentation: divide task in time (sequential phases)
    - examples: speeches or musical performance
    - problem: some complexity comes about due to concurrence of task components
  - fractionization: practice concurrent components of a task separately
    - examples: right and left hand of piano piece, practice shifting and clutching before driving
    - Problem: doesn't train effective time-sharing

LTM and Retrieval

- Real-world tasks are generally recognition, NOT recall
  - Great precision of memory is therefore not required
  - retrieval requires knowledge in the world to operate effectively -- "out of sight, out of mind"
- Encoding specificity: utility of retrieval cues is determined by their similarity to associations made during encoding (example: route vs. survey knowledge)
- The more retrieval cues, the better we remember
  - Tying a rope on your finger
  - Alarms, visual reminders



Mental model

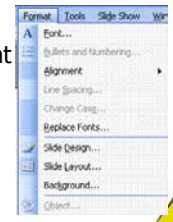
- A person's understanding of the world
  - Partial, informal, unstable
- Properties, interactions, forces, effects
  - E.g. cooking with a gas oven, way a can opener works
- Forged by experience
  - Trial and *error*
  - Consistent with model = believe in model
- Deep versus shallow models (e.g. how to drive a car and how it works)

Case 1: You arrive home hungry, frozen pizza instruction says heat in 350F oven. Set oven to max to speed up?

Case 2: In desperate need hot shower, open tap to the max to speed up hot water?

Designing for mental model

- People have preconceived models that you may not be able to change – so adapt
  - Disconnecting = pulling the wire out, not eject
- Interface must communicate model
  - Help/documentation to communicate your model
  - Visually – make things visible
  - Constraint – restrict what is irrelevant



Error

- There are two types of error
  - Mistakes
    - Wrong intention caused by "wrong" model
    - Minimized through training
  - Action slips
    - Right intention but failed to do it right
    - Because of expert behavior (used to)
    - Minimized through consistency

Mac OS X

Reasoning

- *Using* domains of knowledge & understanding to apply pseudo-logic
- Deduction: Derive logical conclusion from given premises
  - Vegetables are healthy, potatoes are vegetables, chips are potatoes → chips are healthy.
- Induction: Generalisation from instances
  - The swans (I've seen) are white → Swans are white
- Abduction: Reasoning from event to cause
  - When Sam is drunk, he drives fast. Sam passes my car with 90 mph → he is drunk.

Reasoning: Perceptual Judgment

- Perceptual Judgment: Judgments of stimulus magnitudes *above* threshold
- Contrast with *detection*: stimulus at threshold
- Operator must make a judgment about the magnitude of a stimulus that is well above threshold, thus detection is not an issue, e.g.,
  - Will my car fit in that parking space?
  - Do I need to mow the lawn?
  - Is it so cold that I need a jacket?

Reasoning: Perceptual Judgment

- Unidimensional judgments
  - Stimuli vary along one dimension only
  - Observer places stimuli into 2 or more categories
  - With 5 or more categories errors begin to occur much more frequently
- Multidimensional judgments
  - Stimuli vary along more than one dimensions
  - Observer places stimuli into 2 or more categories spread across multiple dimensions
  - *Independent (orthogonal):* change along one dimension does not affect the other dimension
  - *Dependent (correlated):* change along one dimension is accompanied by change along the other dimension

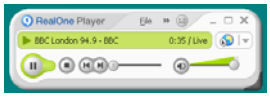
Forming Inferences

- Bottom-up processing
  - current data suggest or deny a hypothesis
  - representativeness heuristic affects this process
- Top-down processing
  - previous experience (knowledge of prior probabilities) helps determine relevant hypotheses
  - affected by both representativeness & availability
- We tend to emphasize the first information we receive when making decisions -- it *anchors* us
- Adjustments are made upon receiving additional information

Causes of Anchoring & Adjustment

- primacy effect and proactive interference?
- we tend to anchor on information that is
  - salient (e.g., information that comes first)
  - simple (e.g., nurses medical decisions)
  - cheap
- we don't anchor based on utility of information
- Human insensitivity to *absence of information*
- *Confirmation Bias:* more weight given to evidence consistent with favored hypothesis than to evidence supporting the contrary hypothesis
  - cognitive "tunnel vision"
  - effect is enhanced under high stress or mental workload

Designing for reasoning



- Affordance: the properties that things (are perceived to) have and how these relate to how the things could be used
- Metaphor: describing a first object as being or equal to a second object in some way
- Mapping: the set of possible relations between objects

Southwest Airlines Home Gate

Attention

- Sternberg (1999): 'Attention acts as a means of focusing limited mental resources on the information and cognitive processes that are most salient at a given moment'
- Aspects of attention:
  - Selective attention
  - Focused attention
  - Divided attention
  - Mental workload
  - Sustained attention, monitoring or vigilance
- Driven by meaning and by change
  - Voluntary: Examine an object, directing gaze etc.
  - Captured by salience and grouping: spatial, intensity, color, size, timbre, pitch, *convention*

Attention

- Selective attention: focusing on a specific aspect of a scene while ignoring other aspects
  - Top-down: mental model
  - Bottom-up: Salient sources (e.g., loud, bright, flashing events), information access trade-offs
- Focused attention: ability to attend to stimulus in presence of distracters
- Divided attention: ability to attend simultaneously to lots of things
- Mental workload: amount of mental effort to perform a task
- Vigilance: ability to pay close and continuous attention over a prolonged period of time

Vigilance

- Signal detection theory
- Technique which measures two components that affect the ability to detect signals
  - Perceptual sensitivity to stimuli – physiologically governed
  - Decision criterion – psychologically governed (variable) point at which you decide that you've detected a signal. Varies from conservative to reckless

		State of the World	
		Signal Present	Signal Absent
Observer Response	"Present"	Hit	False Alarm
	"Absent"	Miss	Correct Rejection

Divided Attention

- There is a general assumption of limited capacity:
  - i.e. resources available to process information are limited
- Two models:
  - Central resource theory: a central bank of resources which is available for all tasks requiring mental effort
  - Multiple resource theory: several banks of specialised resources, e.g. specific to a modality → Doing two similar tasks is harder than doing two dissimilar tasks
- Strategic Control: the degree to which attention can be allocated, relatively, to competing tasks (Wickens & Gopher, 1977)
- Practice: improves the ability to do simultaneous tasks because practice leads to automaticity (Anderson)

Multiple-Resource Theory (Wickens, 1980, 1984)