ACT-R as a Framework for Modeling Human Error

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Overview

- The Error Problem
- Previous Approaches
  - Norman
  - Reason
- Mechanistic approach (MHP)
- New taxonomy based on responsible mechanism

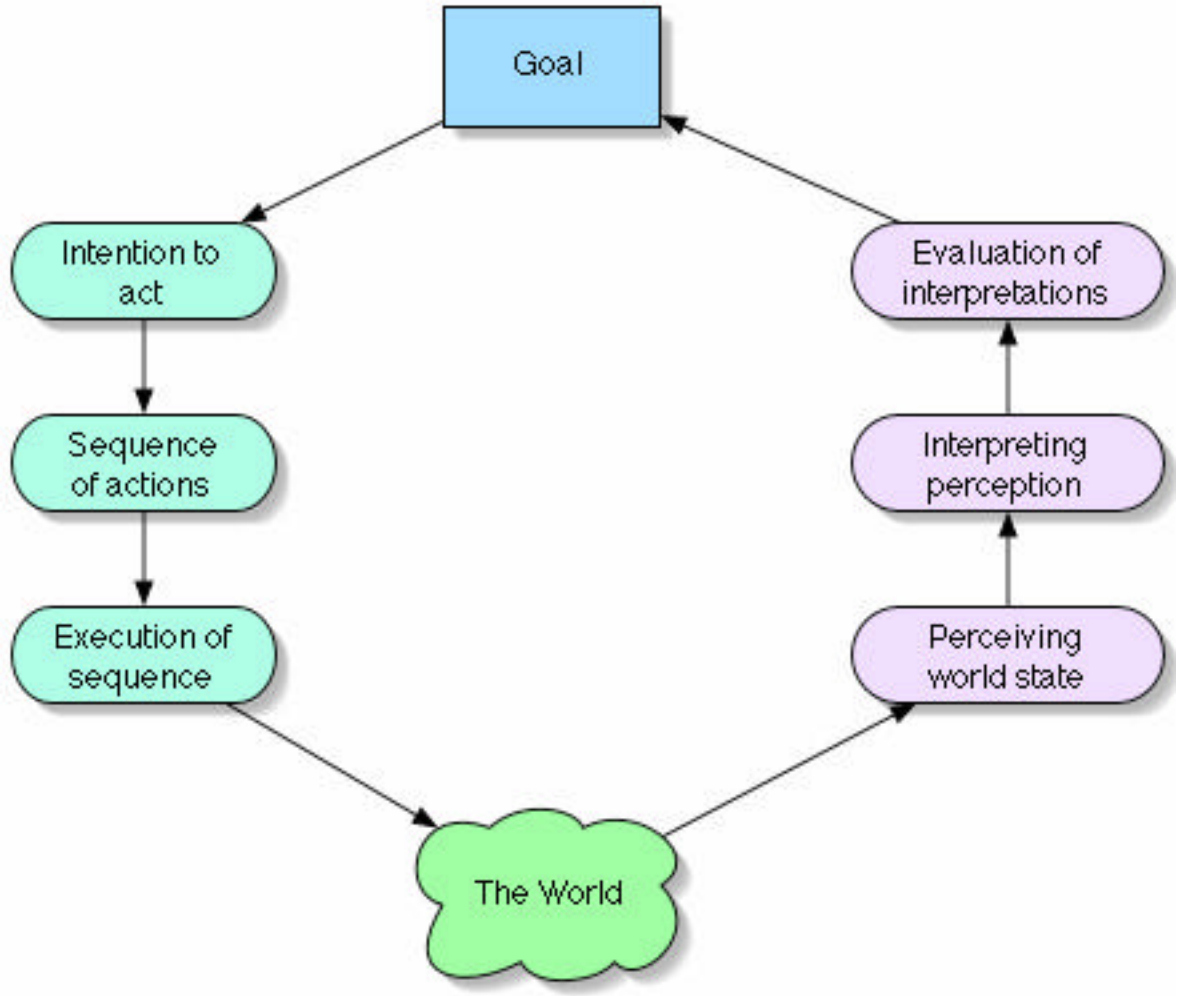
The Error Problem

- Errors, even in the execution of routine procedures by people with, in some sense, the “correct” knowledge, are common
  - Postcompletion errors
  - Forgetting the attachment
  - All kinds of other slips
- Consequences range from negligible to fatal
  - Clearly an important topic
- Surprisingly little research from the cognitive psychology and human factors communities

Why?

- Reasons offered:
  - Senders and Moray: “error is frequently considered only as *result* or *measure* of some other variable, and not a phenomenon in its own right.”
  - The “blame trap”
  - Empirical difficulty
- The Real Problem™
  - Same cognitive-perceptual-motor system that produces correct behavior produces errors
  - Need an account of the whole system
  - And how it interacts with the world!

Norman's "Seven Stages"



Seven Stages

- Can derive an error taxonomy by asking the question “at what stage did the error occur?”
- Can be a useful framework for designing artifacts
- However, it is neither mechanistic or predictive
  - Little is said about the root causes of errors at each stage

Reason's GEMS

- GEMS is "generic error modeling system"
- Based heavily on Rasmussen's Skill-Rule-Knowledge framework
  - Knowledge-based: New situations, behavior guided by interpreted knowledge, reasoning, planning, etc.
  - Rule-based: Familiar situations, governed by rule-plus-exception quick procedures
  - Skill-based: Stored patterns of preprogrammed perceptual-motor sequences, automaticity

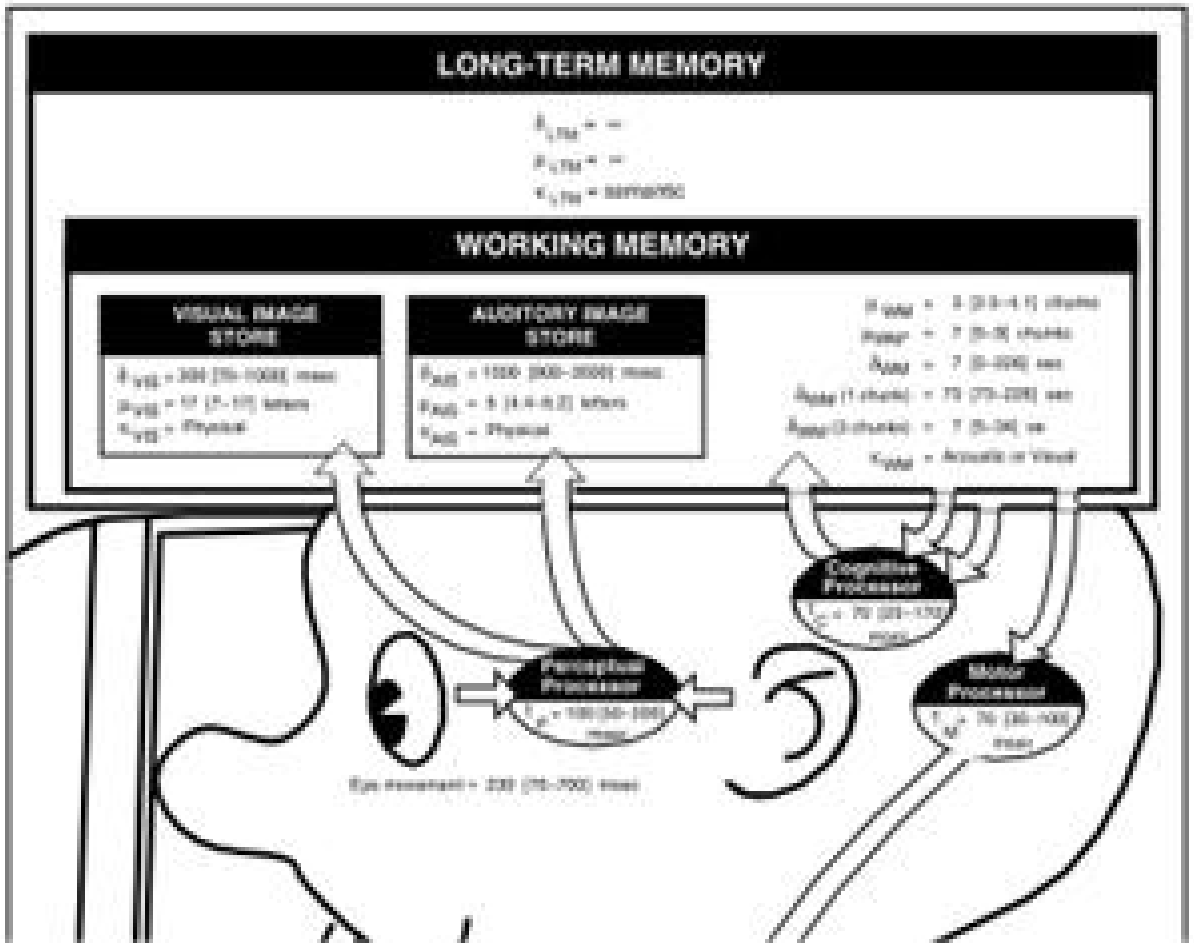
Major Error Headings in GEMS

- Skill-based performance
  - Inattention
  - Overattention
- Rule-based performance
  - Informational overload
  - General rules
- Knowledge-based performance
  - Workspace limitations
  - Several that mirror Kahneman & Tversky heuristics
- Similar problems to the Norman framework

Desiderata

- A framework based on mechanisms, not forms
- Mechanisms need to be specified
- Has to have broad coverage

Model Human Processor



MHP->ACT-R

- LTM/WM -> Declarative Memory
- Cognitive Processor -> Production Memory
- Perceptual Processor & Auditory Store -> Audition Module
- Perceptual Processor & Visual Store -> Vision Module
- Motor Processor -> Motor Module

Declarative Memory Errors

- Retrieval failures
  - Complex issue here; what causes the failure?
  - Overtaxed working memory (not enough W)
  - Not enough rehearsal
  - Weak cues
- Mis-retrievals
  - High similarity
  - High base-level for wrong thing in combination with weak cues
- Retrievals too slow

Procedural Memory Errors

- "Wrong" productions match or fail to match
  - Critical piece of information missing from relevant buffer (e.g., came in late)
  - Goal type hierarchy not good enough here?
- Selection of "wrong" production via PG-C
  - P or C wrong because environment has changed or in different environment
  - Low G favors "bad" solutions
- New kind of problem: Buffer conflicts
  - Goal says one thing, goal-less productions say another

Perceptual Errors

- Attending wrong item
  - Bottom-up
    - Again, not presently in the system, but plans are being considered
  - Top-down
    - Cognitive error?
- Failure to meet time constraints

Motor Errors

- Motor noise (e.g. in aimed movements)
  - Not presently in system, but possible
- Failure to complete within necessary time
- Mis-specification of commands is a cognitive error in this scheme

Combinations and Cascades

- Combinations: Many errors arise because of multiple mechanisms “working” together
  - Visual attention to wrong item results in wrong cue being used for retrieval
- Cascades: Small deviation produces large perturbation later
  - For example, long retrieval results in insufficient time for visual search to find relevant warning, so wrong procedure selected

A Note on Goals

- Since the goal stack is gone, this means goals should be subject to same declarative memory issues as other chunks (only worse)
- Details will depend on what kind of goal management scheme is adopted
  - Link-based stack (Schoelles?)
  - Declarative-memory based GOMS (Schoppek, et al.)
  - Serial attention style (Altmann & Trafton)
  - Display-based reconstruction (a la Gray)
  - Other possibilities exist
- Is goal-management scheme learned and task-dependent?

Conclusions

- The time is (finally) right to consider more comprehensive frameworks for the analysis of errors
  - Comprehensive, mechanism-based theory
- Maybe even prediction!