Scientific Bases of Adult Learning

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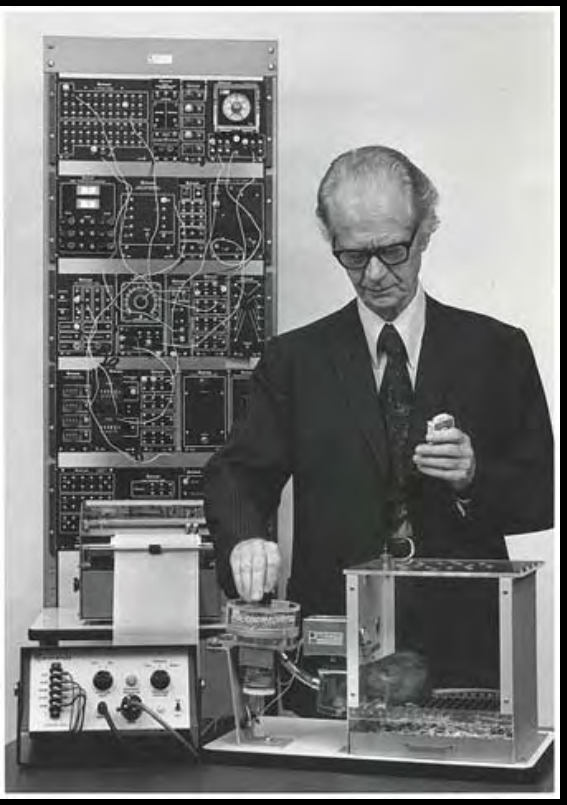
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Overview

- Science of learning today
- Major challenges
- Principles of learning
- Self-regulated learning

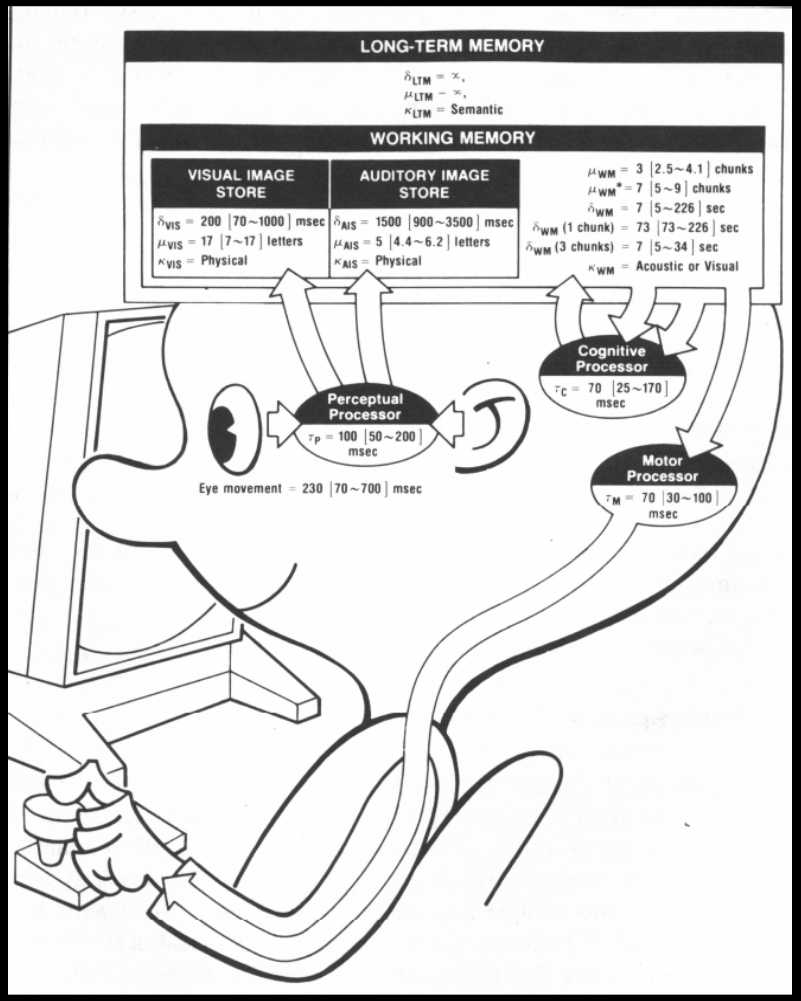
Science of Learning Today

Familiar Images of Learning





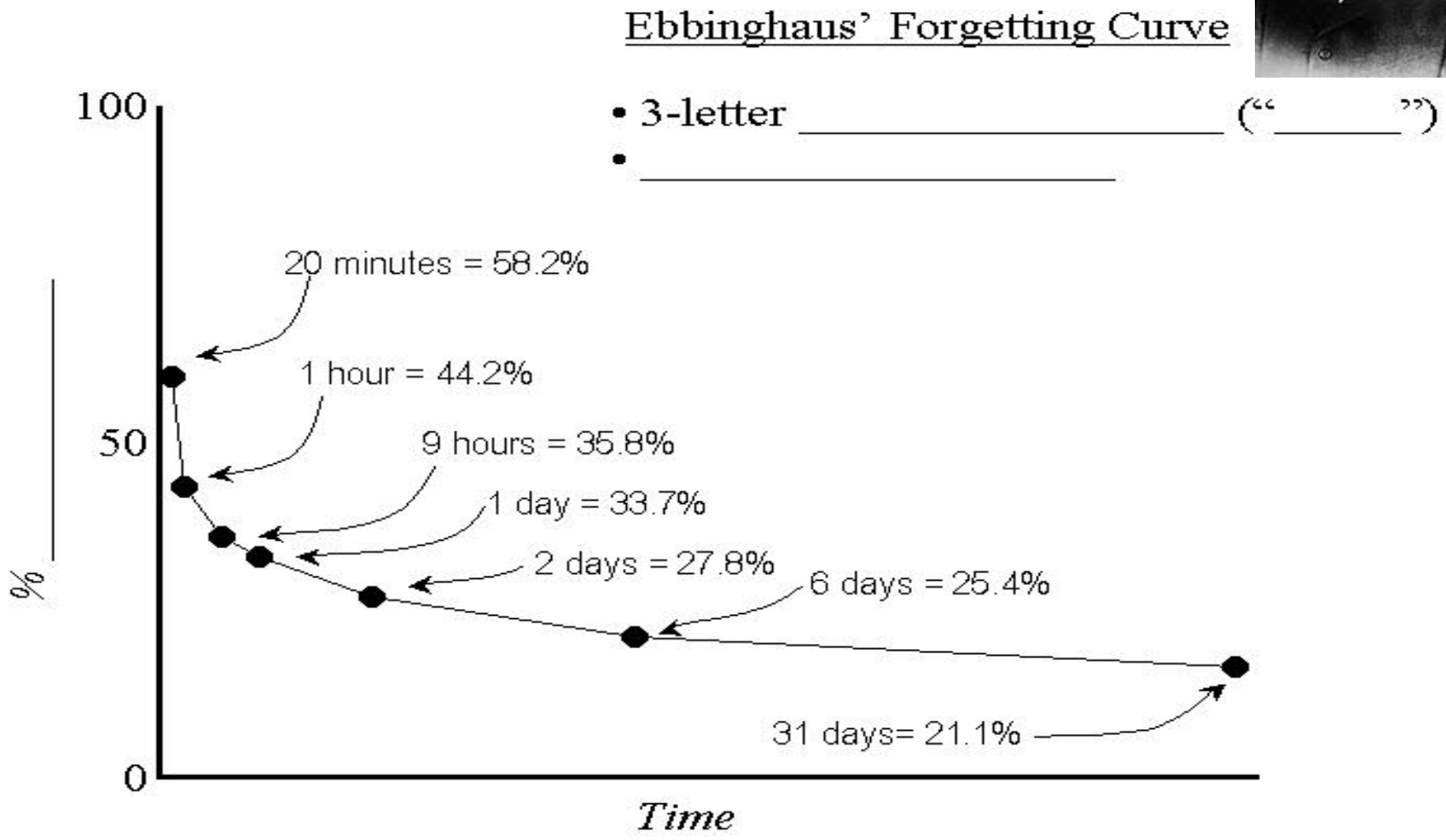




We know how people forget

Hermann Ebbinghaus





We know practice makes perfect

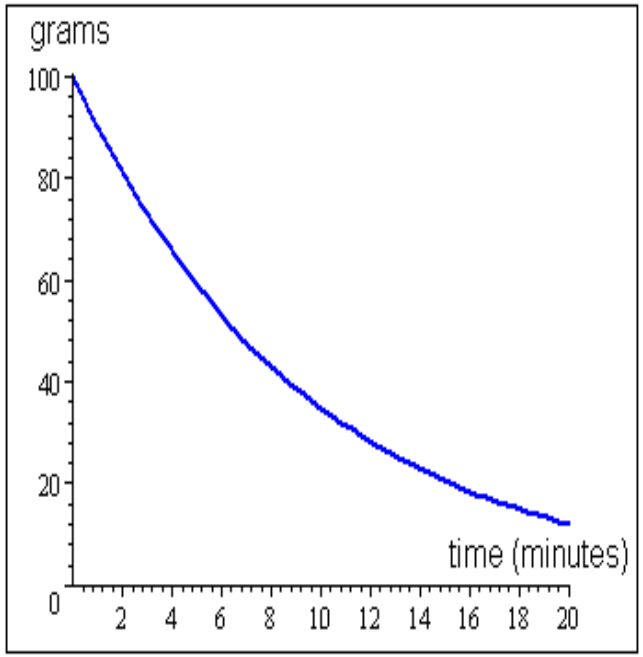
Alan Newell's Power Law of Practice



- The time to perform a task decreases at an exponential rate:

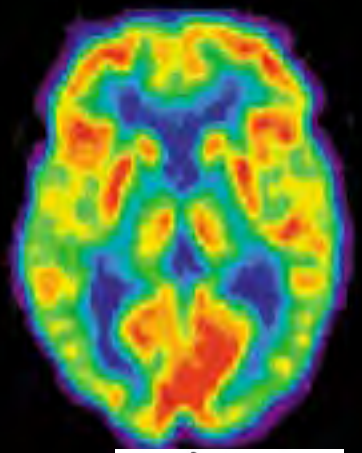
$$T_n = T_1 n^{-a}$$

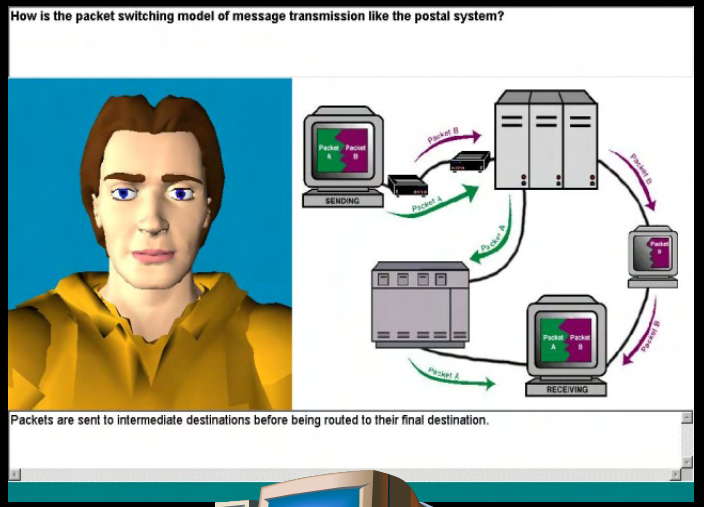
- T_n = the time to perform a task after n trials.
  T_1 = the time to perform a task in the first trial.
  n = the number of trials.
  a = approximately 0.4



Contemporary Images of Learning

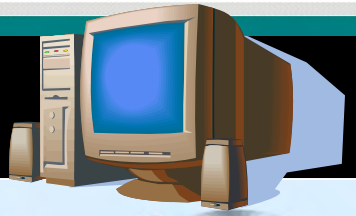




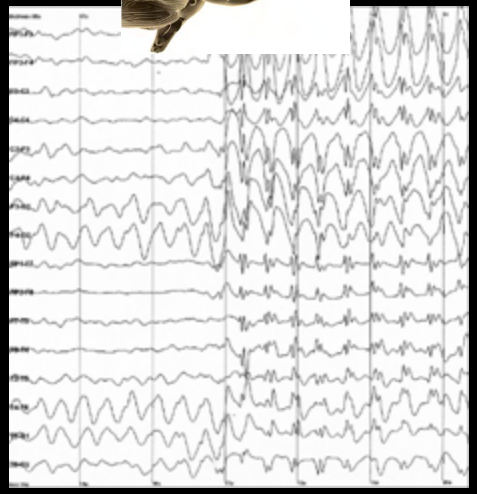














The Sea of Animated Conversational Agents



Landscape of Learning Traditions and Paradigms

Psychology

Associationism
Classical conditioning
Operant conditioning
Modeling
Verbal learning and memory
Mathematical learning theory
Developmental theories

Education

Advanced organizers
Model-scaffold-fade
Inquiry learning
Constructivism
Problem-based curriculum
Apprenticeship learning
Self-regulated learning

Machine learning

Category induction
Connectionism
Case-based
Explanation-based
Bayesian and other statistical
Genetic algorithms

Computer learning environments

Computer-based instruction
Intelligent tutoring systems
Hypertext-hypermedia-web
Multimedia and virtual reality
Interactive simulation
Animated pedagogical agent
Games

Challenges

Characteristics of learners that we wish were better

- Comprehension calibration
- Focus on deep rather than shallow knowledge
- Tolerance for boring learning material
- Tolerance for complex learning material
- Learner question asking
- Distributing learning over time
- Precise articulation of knowledge
- Monitoring of frustration and confusion
- Self-regulated learning

Pedagogical strategies *rarely* used by human tutors and instructors

- Socratic tutoring (*Collins, Stevens*)
- Modeling-scaffolding-fading (*Rogoff, Gardner*)
- Reciprocal teaching (*Brown, Palincsar*)
- Building on prerequisites (*Gagne*)
- Sophisticated motivational techniques (*Lepper*)
- Scaffolding Self-regulated learning strategies (*Azevedo, Winne*)

Human and computer tutors have impressive learning gains

.4 Unskilled human tutors

(Cohen, Kulik, & Kulik)

.5 Peer tutoring

(Fuchs, Topping)

.8 AutoTutor

(Graesser and colleagues)

1.00 Intelligent tutoring systems

PACT (Anderson, Corbett, Aleven, Koedinger)
Andes, Atlas (VanLehn)
Diagnoser (Hunt, Minstrell)
Sherlock (Lesgold)

Principles of Learning

Cognitive Learning Principles

- **Institute of Education Sciences**
  - Practice Guides for Teachers
  - Organizing Instruction and Study to Improve Student Learning
    - What are the principles?
    - What is the evidence?
    - How can they be applied in schools?
  - ***Pashler, Bain, Bottge, Graesser, Koedinger, McDaniel, & Metcalf (2007).***
  - http://ies.ed.gov/ncee/wwc/pdf/practiceguides/20072004.pdf

7 Learning Principles

1) Space learning over time.
2) Interleave worked example solutions with problem solving exercises.
3) Combine graphics with verbal descriptions.
4) Connect and integrate abstract and concrete representations of concepts.
5) Use quizzing to promote learning.
6) Help students allocate study time effectively.
7) Ask deep explanatory questions.

25 Learning Principles

- **APA and Association for Psychological Sciences**
  - **Lifelong learning at Work and at Home**
  - **25 principles**
  - ***Graesser, Halpern, and Hakel (2008)***
  - **www.psyc.memphis.edu/learning/whatweknow/index.shtml**



Principles 1–5

1. **Contiguity Effects**. Ideas that need to be associated should be presented contiguously in space and time.

2. **Perceptual-motor Grounding**. Concepts benefit from being grounded in perceptual motor experiences, particularly at early stages of learning.

3. **Dual Code and Multimedia Effects**. Materials presented in verbal, visual, and multimedia form richer representations than a single medium.

4. **Testing Effect**. Testing enhances learning, particularly when the tests are aligned with important content.

5. **Spacing Effect**. Spaced schedules of studying and testing produce better long-term retention than a single study session or test.

Principles 6–10

6. **Exam Expectations**. Students benefit more from repeated testing when they expect a final exam.

7. **Generation Effect**. Learning is enhanced when learners produce answers compared to having them recognize answers.

8. **Organization Effects**. Outlining, integrating, and synthesizing information produces better learning than rereading materials or other more passive strategies.

9. **Coherence Effect**. Materials and multimedia should explicitly link related ideas and minimize distracting irrelevant material.

10. **Stories and Example Cases**. Stories and example cases tend to be remembered better than didactic facts and abstract principles.

Principles 11–15

11. **Multiple Examples**. An understanding of an abstract concept improves with multiple and varied examples.

12. **Feedback Effects**. Students benefit from feedback on their performance in a learning task, but the timing of the feedback depends on the task.

13. **Negative Suggestion Effects**. Learning wrong information can be reduced when feedback is immediate.

14. **Desirable Difficulties**. Challenges make learning and retrieval effortful and thereby have positive effects on long-term retention.

15. **Manageable Cognitive Load**. The information presented to the learner should not overload working memory.

Principles 16–20

16. **Segmentation Principle**. A complex lesson should be broken down into manageable subparts.

17. **Explanation Effects**. Students benefit more from constructing deep coherent explanations (mental models) of the material than memorizing shallow isolated facts.

18. **Deep questions**. Students benefit more from asking and answering deep questions that elicit explanations (e.g., why, why not, how, what-if) than shallow questions (e.g., who, what, when, where).

19. **Cognitive Disequilibrium**. Deep reasoning and learning is stimulated by problems that create cognitive disequilibrium, such as obstacles to goals, contradictions, conflict, and anomalies.

20. **Cognitive Flexibility**. Cognitive flexibility improves with multiple viewpoints that link facts, skills, procedures, and deep conceptual principles.

Principles 21–25

21. **Goldilocks Principle**. Assignments should not be too hard or too easy, but at the right level of difficulty for the student's level of skill or prior knowledge.

22. **Imperfect Metacognition**. Students rarely have an accurate knowledge of their cognition so their ability to calibrate their comprehension, learning, and memory should not be trusted.

23. **Discovery Learning**. Most students have trouble discovering important principles on their own, without careful guidance, scaffolding, or materials with well-crafted affordances.

24. **Self-regulated Learning**. Most students need training on how to self-regulate their learning and other cognitive processes.

25. **Anchored Learning**. Learning is deeper and students are more motivated when the materials and skills are anchored in real world problems that matter to the learner.

Genres of Computer Learning Environments

- Computer-based training
- Multimedia
- Interactive simulation
- Hypertext and hypermedia
- Intelligent Tutoring Systems
- Inquiry-based information retrieval
- Animated pedagogical agents
- Virtual environments with agents
- Serious games
- Computer supported collaborative learning

Self-Regulated Learning

Three Central Claims

- **Self-regulation depends on meta-knowledge**
- **Self-regulated learning and meta-knowledge is unspectacular in adult learners**
- **Adults need direct training on these sophisticated skills**

SRL Frameworks and Models

(Azevedo, Pintrich, Schunk, Winne, Zimmerman)

PHASES / AREAS	Cognition	Motivation / Affect	Behavior	Context
Forethought, Planning, Activation	▪ Goal setting ▪ PKA	▪ Goal orientation ▪ Task value ▪ Efficacy judgment	▪ Time and effort planning	▪ Perception of task ▪ Perception of context
Monitoring	▪ JOL ▪ FOK			▪ Monitoring changing task conditions
Control	▪ Learning strategies		▪ Increase / decrease effort ▪ Help-seeking behavior ▪ Persistence	▪ Change or renegotiate task
Reaction and Reflection	▪ Schema adaptations	▪ Attributions		▪ Evaluation of task ▪ Evaluation of context

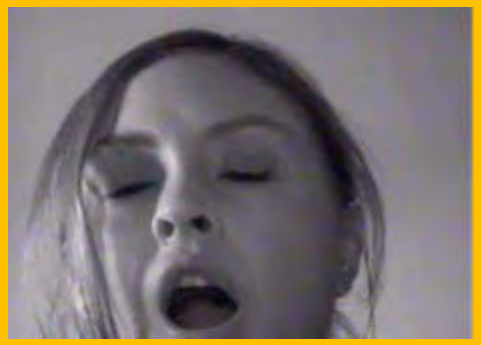
Meta-Knowledge Examples

	Tutor	Student
Pedagogy	Prompt > tell	Effort > talent
Communication	Tutor tell ≠ Student savor	Expose >hide errors
Cognition	Cognitive disequilibrium	Deep > shallow
Emotion	Confusion = learning opportunity	Count to 10

Emotions During Learning

(D'Mello, Graesser, Craig)

Boredom
(23%)



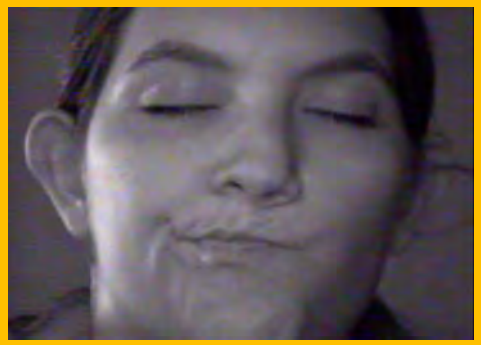
Confusion
(25%)

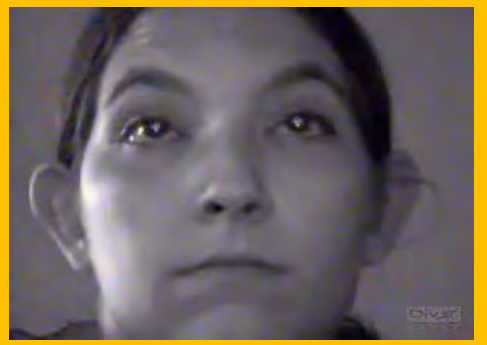


Delight
(4%)







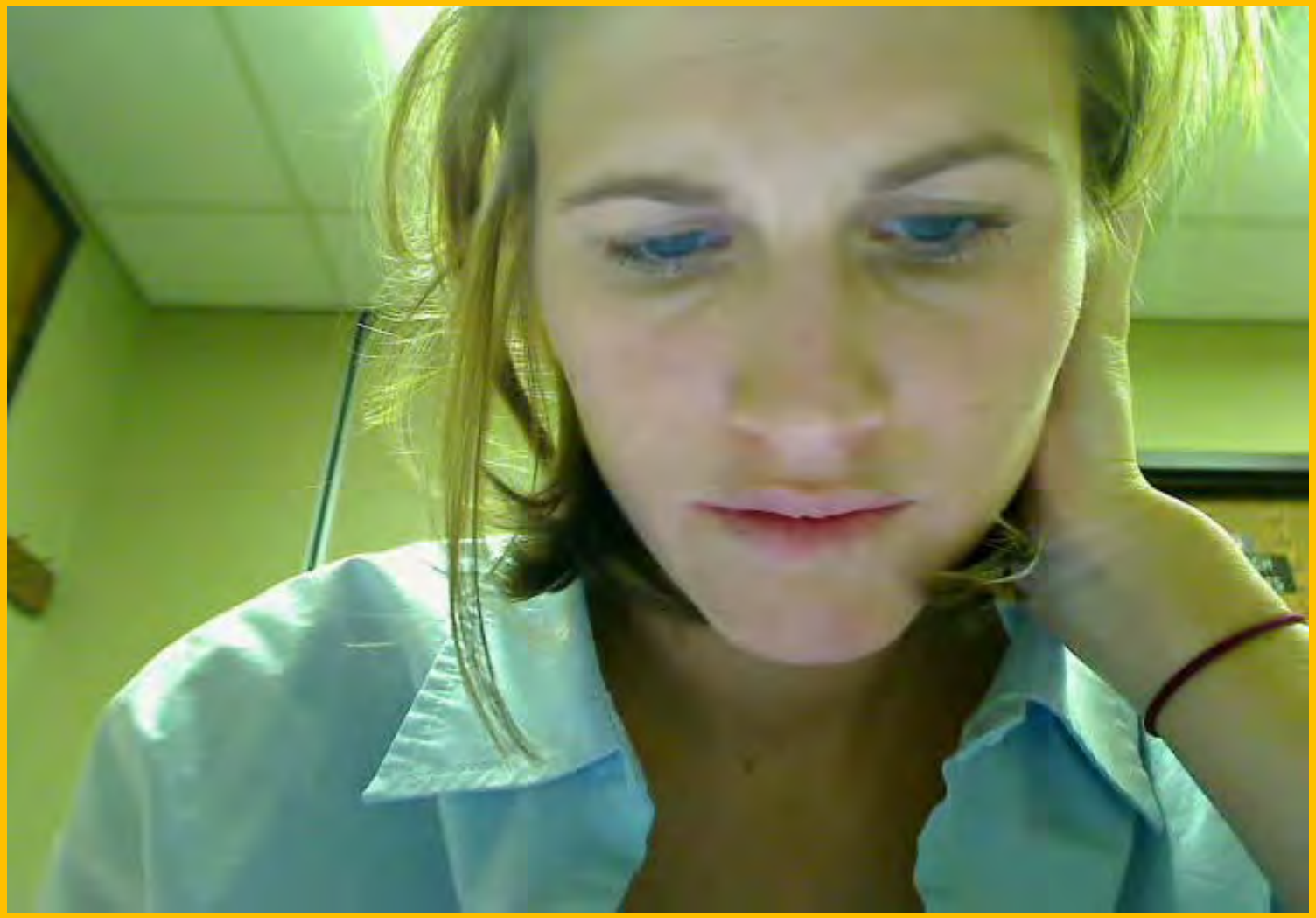


Flow
(28%)

Frustration
(16%)

Surprise
(4%)

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D'Mello, S., & Graesser, A.C. (2010). Multimodal semi-automated affect detection from conversational cues, gross body language, and facial features. *User Modeling and User-adapted Interaction.*

Emotions and Complex Learning



- **Emotions (affective states) are inextricably bound to deep learning.**
- **Positive emotions are:**
  - **engagement → flow → delight → excitement → eureka**
- **Negative emotions are:**
  - **confusion → irritation → frustration → anger → rage**



Operation ARIES!

Acquiring Research Investigative and Evaluative Skills
(Millis, Halpern, Graesser, Britt, Magliano, Wiemer)

- Scientific reasoning
- Electronic textbook
- Periodic questions
- Critique experiments and newspaper clips
- Game context with aliens
- Trialogs with tutor and student agents





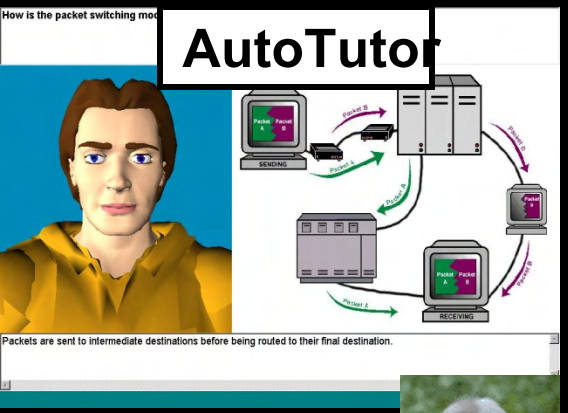



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Memphis Agent Environments

AutoTutor



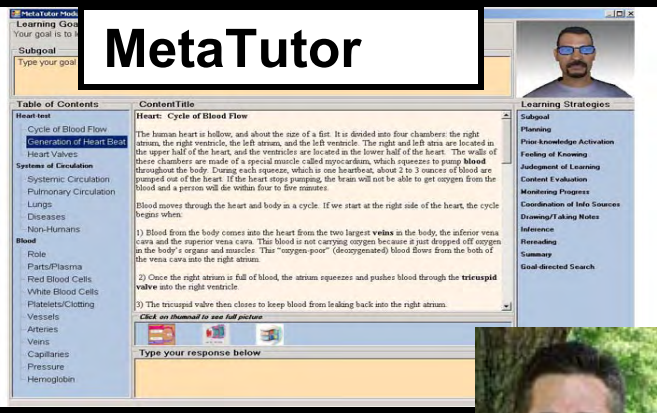


iSTART





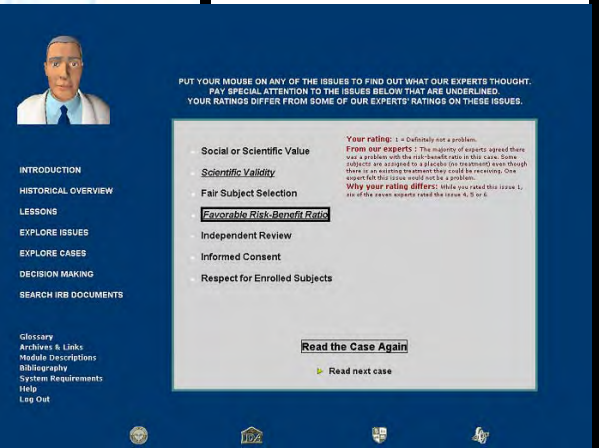
MetaTutor





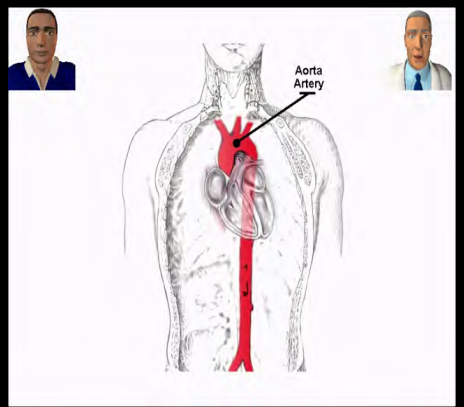


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