Cognitive Science and Educational Technology I
Dr. Jan L. Plass

New York University • ECT Program

E19.2174

Cognitive Science

and Educational Technology I

Dr. Jan L. Plass

New York University • ECT Program

© 2009-11, Jan L. Plass

Cognitive Science

Understanding of
• Human Memory
• Encoding & Retrieval Processes
• Cognitive Processes in Learning
• Mental Models, Schemata
• Theories of Multimedia Learning

Cognitive Science

Overview
• Human Memory
• The Brain
• Sensory Memory
• Short-Term Memory, Working Memory
• Implication for Design of Instructional Technology

Cognitive Science

The Human Brain
• Macromolecular level: Anatomy
• Microscopic Level: Neurons and Glia
• Cellular Level: Brain cells

Cognitive Science

Brain Anatomy
• Frontal Lobe: motor activity, including speech, integrates personality with emotion and transforms thought into action
• Parietal lobe: sensory information from opposite side of body, integration of vision and sound
• Temporal lobe: hearing, involved in learning, memory, emotion
• Occipital lobe: visual perception
• Cerebellum: Balance, posture, movement
Cognitive Science

The Human Brain

- Macromolecular level: Anatomy
- Microscopic Level: Neurons and Glia
- Cellular Level: Brain cells

Cognitive Science

Neuron

- Cell Body
- Axon
- Myelin sheath
- Schwann cell
- Node of Ranvier
- Dendrites
- Synapses

Cognitive Science

Principal Motor Domains

- Motor cortex
- Primary motor cortex (M1)
- Premotor cortex (PMA)
- Supplementary motor cortex (SMA)

Cognitive Science

Microscopic Level

- Neuron: cellular unit of the central and peripheral nervous systems
- Glia: “glue” binds neurons together
- Neurons communicate by means of neurotransmitters acting across synapses
- 50–100 billion neurons in brain
- 1 Million billion connections between neurons
- 2.5 Million neurons generated per minute during prenatal life
Cognitive Science

The Human Brain

• Macromolecular level: Anatomy
• Microscopic Level: Neurons and Glia
• Cellular Level: Brain cells

Cognitive Science

Based on genetic code in DNA
• Approx. three Billion DNA bases
• Difference to chimpanzees: 1%
• Specialization of brain cell: Information transfer

Brain cells

Cognitive Science

Overview

• Human Memory
  • The Brain
  • Sensory Memory
  • Short-Term Memory, Working Memory
• Implication for Design of Instructional Technology

Cognitive Science

Vision

• Light and Neural Activity Video:
  • http://www.youtube.com/watch?v=AuLR0kzw8BU

Cognitive Science

Sensory/Working Memory

Discuss in Groups of 3-4 Students (10min.)

Describe how the properties of sensory and working memory are optimized to fulfill the different functions of the two systems. Use examples to illustrate your points.

– How did Sperling (1960) show that sensory memory is temporarily, rather than visually limited?
– Be prepared to report the results of your discussion to class

Sensory/Working Memory

• Holds information in a relatively raw, unprocessed form for a short time after the physical stimulus is not longer available
• Items remain in sensory memory for about 2 sec.
• Storage capacity of sensory memory is much larger that short-term memory
• Information in sensory memory is a fairly accurate representation of the stimulus
Cognitive Science

Sensory Memory

Reason/Need
- Constantly and rapidly changing stimuli that bombard your senses
- Need to keep an accurate record of the sensory stimulation for a brief time while we select the most important stimuli for further processing

Components
- Visual sensory memory (iconic memory)
  - Information lasts about 1/4–1/2 s
- Auditory sensory memory (echoic memory)
  - Information lasts about 2–4 s
  - Long and short auditory storage?

Question
How can the concepts of Selective Attention and Automaticity be used to improve the design of multimedia learning environments?

Pattern Recognition
- Thought to be accomplished by
  - Template matching
  - Prototype model
  - Feature analysis

What are the potential problems with each of these methods?

Overview
- Human Memory
  - The Brain
  - Sensory Memory
  - Short-Term Memory, Working Memory
- Implication for Design of Instructional Technology

Information Processing
Cognitive Science

Working Memory

• Temporary storage of information in thinking and problem solving
• Distinct components: phonological (speech-based) and visuo-spatial
• Capacity is limited to around 7 +/-2 items, can be extended by means of efficient coding systems (Miller, 1956)

Working Memory

Important Terms
• Chunking
• Rehearsal
• Encoding

Miller (1956)

• Span of absolute judgment (capacity to transmit information): about 2.5 bits (6 categories)
• Relationship of number of variables, total capacity, and accuracy for any particular variable

Baddeley & Hitch Model

• Central executive
  – Coordinates information from two slave systems
• Articulatory Loop
  – Phonological store, holds acoustic information for 1-2s
  – Articulatory control process (inner speech)
• Visuo-Spatial sketch pad
  – Processing of imagery:
    – Patterns
    – Spatial Relations

Baddeley & Hitch, 1974
Questions

What is the difference between short-term memory and working memory?

What is the relationship between working memory capacity and intelligence?

Scenario

Cognitive Science

Questions

What is the importance of this component view of WM for the design of multimedia learning materials?

How can the design of such materials take advantage of the processes described by this model?

Working Memory

• Capacity of WM described in terms of fixed number of independent patterns (chunks)
• Individual differences in WM capacity as cause for general differences in performance across different tasks

Scenario

Cognitive Science

Challenges to Traditional View

• Memory span of normal adults only weakly correlated with performance in skilled everyday activities such as text comprehension (Daneman & Merikle, 1996)
• Some individuals with brain damage show normal performance on complex tasks such as text comprehension, even when they have severely impaired immediate memory performance (Martin, 1993)

Scenario

Cognitive Science

Challenges to Traditional View

• For Reasoning and Comprehension tasks (rather than just recall) reliable WM: 3-4
  => not enough capacity for complex mental processing unless additional activity-specific resources are proposed

THAT IS THE TRADITIONAL VIEW:
BASIC CAPACITY APPROACH
New Approach for Working Memory is needed: 

Transient-Storage Approach

- Working memory is the transiently activated portion of LTM
- Limits on the number of elements in working memory are not determined by a fixed number but rather by the amount of available activation
- Working memory can sometimes contain over 20 units at one time
- Fast decay reduces amount of information that can be recalled in test

Definition (Baddeley & Logie, 1999)

- WM comprises those functional components of cognition that allow humans to comprehend and mentally represent their immediate environment, to retain information about their immediate past experience, to support the acquisition of new knowledge, to solve problems, and to formulate, relate, and act on current goals

Definition (Miyake & Shah, 1999)

- Mechanisms and processes that are involved in the control, regulation, and active maintenance of task-relevant information in the service of complex cognition
- Consists of a set of processes and mechanisms and is not a fixed place in the cognitive architecture
- Involves multiple representational codes and/or different subsystems
- Contents: mainly activated LTM representations

Small Group Discussion (10 min.)

- How do the limitations of WM manifest themselves in the instructional use of multimedia or hypermedia environments?
- Use the Virtual Knee Surgery web site as basis for your discussion
Cognitive Science

Overview

• Human Memory
  • The Brain
  • Sensory Memory
  • Short-Term Memory, Working Memory
• Implication for Design of Instructional Technology

Instructional Design

ISD & Cognitive Science

Cognitive Approach to Media Selection

Cognitive Approach to Interface Design

Design from Emotional Perspective

Multimedia Design Principles

Cognitive Task Analysis

Assess Needs to Identify Goals

Conduct Instructional Analysis

Analyze Learners and Contexts

Write Performance Objectives

Develop Assessment Instruments

Develop Instructional Strategies

Develop & Select Instructional Materials

Design & Conduct Formative Evaluation of Instruction

Design & Conduct Summative Evaluation of Instruction

Revise Instruction