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

Cognitive Science
Overview
• Cognitive Load Theory (CLT)
  • Sources of Cognitive Load
  • Split Attention Effect
  • Redundancy Effect
  • Applying CLT in Design of Multimedia Instruction
  • Measurement of Cognitive Load

Cognitive Science
Assumptions
• Learning through Schema acquisition
• Limited Capacity of Working Memory
• Virtually Unlimited Capacity of LTM

Cognitive Science
Main Claim
• Three sources for cognitive load:
  • Intrinsic Load
  • Extrinsic Load
  • germane Load

Cognitive Science
Presentation
• Presentation: Cognitive Load Theory
**Cognitive Science**

**Cognitive Load Theory**

**Intrinsic Cognitive Load**
- Induced by the inherent nature of the learning content
- Intrinsic Complexity of the Core Information
- Imposed by instructional materials (Level of Element Interactivity)

**Cognitive Science**

**Element Interactivity**
- Extent to which the elements of a task can be meaningfully learned without having to learn the relations between any other elements
- **Low element interactivity**: Elements of learning task can be learned in isolation, i.e., they can be assimilated serially
- **High element interactivity**: Elements are related in a manner that requires them to be assimilated simultaneously

**Cognitive Science**

**Measurement of Element Interactivity**
- Precise measurement unobtainable—nature of ‘element’ is learner-dependent
- Assuming the knowledge level of a learner, estimate of number of interacting elements that must be acquired simultaneously in order to learn a certain task is possible
- Identify set of elements that each are meaningful only in conjunction with the other elements in the set

**Cognitive Science**

**Extraneous Cognitive Load**
Induced by manner of the material presentation:
1. Cognitive Activities required by the instructional strategy to comprehend the instruction (goals, etc.)
2. Presentation of the information, e.g.,
   - Split-Attention principle
   - Redundancy principle

**Cognitive Science**

**Presentation**

**Split-Attention Principle**
Avoid presentation of information in ways that require learners to split their attention between, and integrate, multiple sources of information (Ayres & Sweller, 2005).

Occurs only when:
- Multiple sources of physically or temporally separated information are logically related
- Integration of the information in these sources is essential for learning
Cognitive Science

Modality Principle
Presenting narratives related to visual information in auditory mode can enhance learning compared to using a visual mode only (Low & Sweller, 2005)

- Multiple sources of visual and auditory information are logically related
- Integration of the information is essential for learning

Redundancy Principle
Redundant material interferes with, rather than facilitates, learning (Sweller, 2005)

- Same information is presented in multiple formats
- Unnecessary elaboration of information is presented
- Effect depends on learner’s prior knowledge

Extraneous Cognitive Load

Germane Cognitive Load
- Internal organization; integration; schema construction
- Mental effort invested by the learner to comprehend material

Total Cognitive Load =
- Intrinsic Cognitive Load (Content)
+ Extraneous Cognitive Load (Artificial)
+ Germane Load (Effort)
Scenario

Cognitive Science

Group Discussion–10 min.

- Discuss in groups of 4–5
- How do the different types of cognitive load affect learning?
  - Define each type of load
  - Use an example to describe how they affect learning
  - Be prepared to share your ideas with the class

Cognitive Load Theory

Mechanisms to Reduce Cognitive Load

- Schema Acquisition
- Automation

Cognitive Science

Schema Acquisition

Schema

- Cognitive construct that organizes the elements of information according to the manner used
- Determines how new information is dealt with
- Organize elements (units to be learned) and can act as elements themselves in higher order schemata

Instructional Design Implications

- Consider Intrinsic Load (complexity of materials)
- Reduce extraneous load for high-intrinsic load materials:
  - Goal-free problems, or reduced-goal-specificity
  - Worked examples: studying given solutions and examples reduces cognitive load
- Cognitive Load Effects (Redundancy, Split-Attention)
- Cognitive resources needed for mental integration
### Function of Learning

- Store automated schemata in long-term memory.
- Commonality of schema acquisition and automation: substantially reduce working memory load.

\[ \Rightarrow \text{Schema: Chunking individual elements into single element} \]

\[ \Rightarrow \text{Automatic processing requires less working memory space} \]

### Measuring Cognitive Load

#### Current Methods
- **Indirect measurement**
  - Acquired knowledge (in experimental designs): the less knowledge is acquired, the more CL is assumed.
  - Correlation with behavioral data:
    - Time on task: learning time increases with increased CL.
    - Navigation errors (e.g., in hypertexts).
    - Eye tracking observation.
- Subjective rating
  - Questionnaires.
- Direct measurement
  - Dual task (with text books).

#### Alternative Method
- **Direct Measurement**
  - Applied to multimedia learning: Multimedia learning scenario (as primary task) + a secondary task requiring the same resources.
  - If different forms of multimedia learning scenarios vary in the amount of CL, then secondary task performance varies in relation to the load induced by the learning system.
  - Thus: secondary task performance is a measure for CL (Free CL).

### Multimedia Learning

- **Modality effect:** Simultaneous visual-only presentation of text and pictures produces more (visual) CL than audiovisual presentation of the same material.
- This results in a lower amount of knowledge acquisition from visual-only compared to audiovisual learning material.

### Hypothesis

- Presenting the learner with a simultaneous visual secondary task, performance on secondary task will be better with an audiovisual learning system serving as primary task than with a visual-only learning system of the same content.
Measuring Cognitive Load

Experimental Validation

Method
- 2 Experiments with different learning systems but the same secondary task
- Each Experiment with n = 10 participants
- All-within-subjects design with repeated measures
- Independent Variable: Modality of information presentation (visual vs. audiovisual) + (single task condition--secondary task alone) = 3 measurement conditions within subject
- Repeated measures within each condition
- Dependent Variable: Secondary Task Performance

Measuring Cognitive Load

Scenario Measuring Cognitive Load

Method
- Primary task: Learning system
  - "How the human cardio-vascular system works"
  - 22 screen pages with verbal and pictorial information
  - Visual or audiovisual presentation, alternating page-wise
- Secondary task: Simple visual reaction time task
  - Presentation of a single letter centered above the primary task
  - Occasional change of the letter’s ink color from black to red
  - Subject response to color change: press key

Experiment 1

Primary task: Learning system
- "A tour guide through Florence"
- 18 Screen pages with verbal and pictorial (graphical maps and photos) information
- Visual or audiovisual presentation, alternating page-wise

Secondary task: Simple visual reaction time task (same as in Experiment 1)

Results

For both Experiments:
- Sign. main effect of exp. condition in RM-ANOVA
- Sign. post-hoc t-tests for all differences
- Order of reaction times identical for each participant

Discussion

Dual Task Approach

Experiments
- In line with Modality Effect (Brünken & Leutner, 2001)
- In line with predictions of Cognitive Load Theory

Dual Task Approach
- Demonstrated feasibility of method
- Provides method of directly assessing CL in multimedia learning

Theoretical Implications
- Convergent validity of two methods for measurement of Cognitive Load in multimedia learning, demonstrated for modality effect
- Primary task performance (learning outcome)
- Secondary task performance (reaction time)
- Also suitable for verification of other effects (e.g., prior knowledge reduces Cognitive Load, contiguity effect, expertise reversal effect...)
- Implementation for auditory modality