Cognitive Science Overview

- Individual Differences
- Design of Adaptive Learning Environments
- Research on Individual Differences

Cognitive Science Individual Differences

Examples
- Intelligence
- Ability
- Preferences
- Learning Style
- Personality Type
Learner Characteristics
- Demographic
- Physiological
- Experience
- Learning Style
- Aptitude
- Knowledge

Group Discussion
You are asked to develop an adaptive learning environment for teaching the History of the Gulf War. How would you approach this project?

Effect of Individual Differences
Assumptions:
- Good design supports learners’ individual characteristics
- If learner preferences or abilities are not supported, learning suffers

=> Is that always so? Can you name examples?
Group Discussion

You are asked to develop an adaptive learning environment for teaching the History of the Gulf War. How would you approach this project?

1. Identify relevant individual differences that affect the cognitive processes involved in instructional strategies.

Individual Differences

Categories of Individual Differences

- Intelligence (General Mental Ability)
- Second Order Abilities (Fluid, Crystallized, Visual)
- Cognitive Abilities (Primary)
- Cognitive Styles
- Learning Styles
- Personality Types

Cognitive Abilities

- Content and level of cognitive activity
- Competencies, maximal performance
- Unipolar measures, value directional
- Affected by content domain, nature of task
- Enable people to perform tasks
- Examples: spatial ability; verbal ability
Verbal Ability

- Ability to learn vocabulary and comprehend text
- Vocabulary tests correlate with capacity of verbal WM (Gathercole & Baddeley, 1993)
- Relationship with vocabulary learning in second language (Atkinson & Baddeley, 1998)

Spatial Ability

- Ability to generate, maintain and manipulate mental visual images (Carroll, 1993)
  - Visualization (Cards, Figures, Flags)
  - Spatial relations (Card rotation)
  - Closure speed (Gestalt completion)
  - Closure flexibility (Hidden figures/patterns)
  - Perceptual speed (Identical pictures)
- Spatial relations ability expected to affect processing of visual information

Cognitive Styles

- Manner and form of learning
- Propensities, typical performance
- Bipolar measures, value differentiated
- Control way in which tasks are performed
- Stable over time and content
- Examples: visual/haptic, holist/serialist
Scenario: Cognitive Science

Learning Styles
- General tendencies to prefer to process information in different ways
- Kolb (1975) (perceiving, processing)
- Dunn & Dunn (1974) (environmental, sociological, emotional, physical variables)
- Gregorc (1982) (perceiving, processing)

Individual Differences

Personality Types
- Sum of inherited and learned mental qualities
- Aristotle: sanguine, melancholic, choleric, phlegmatic
- Freud: ego, id, super ego
- Jung's personality types
- Miller (1981) (analytic - objective - holistic - subjective; emotional stability/instability)

Group Discussion

You are asked to develop an adaptive learning environment for teaching the History of the Gulf War. How would you approach this project?

1. Identify relevant individual differences that affect the cognitive processes involved in instructional strategies
2. Identify their expected effect.
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Multimedia Learning

Media Effects
Is one medium better than another?

Multimedia Effects
Is multimedia instruction effective?
Single vs. multiple representations

Interaction Effects
For whom is multimedia effective?

(Mayer, 1997)

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ATI Research

Attribute x Treatment Interaction

• Interaction between alternative attributes, traits, or aptitudes and alternative treatments
• Example:
  – Low- vs. high-structured environment for low vs. high prior knowledge learners
  – Visual vs. Verbal treatment for Visualizers vs. Verbalizers

Cognitive Load, Multimedia, and Abilities

Research Design

• Study 1 (Plass, Chun, Mayer, Leutner, 1998)
  • Choice of Multimedia Annotations in Second-Language Reading Text
  • Visualizer and Verbalizer Preferences

• Study 2 (Plass, Chun, Mayer, Leutner, 2003)
  • Four Treatment Groups: Visual x Verbal Annotation
  • Spatial and Verbal Ability
Cognitive Load, Multimedia, and Abilities

Study 1

Method

• Authentic German Reading Text (Heinrich Böll)
• Within-subject design: Choice of Annotations (Visual or Verbal) for Vocabulary Words
• Preferences: VV-BOS (Visualizer/Verbalizer Behavioral Observation Scale)
• Vocabulary Test (Recognition)
• Comprehension Test (Recall Protocol)
• 103 Participants (college students)

Study 1–Results

Vocabulary Acquisition

• No main effect of treatment or preference
• Multimedia Effect for Vocabulary Acquisition
• Significant interaction of learning preferences and annotation type
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Multimedia Effect

ATI Research

Attribute x Treatment Interaction
- Significant Interaction of Learning Preferences and Annotation Type, $F(1,72) = 45.9$, $MSE = 90.40$, $p<.001$

Study 1 – Results (Comprehension)

Text Comprehension
- No main effect of learning preferences
- Main effect of annotation type (annotated verbally only or visually and verbally)
- Interaction of learning preference and annotation type used to annotate a proposition
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Study 1 Results (Comprehension)

Significant interaction of Learning Preferences and Annotation type:
F(1,72) = 4.42, MSE = 429.20, p < .05

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Study 1 Summary

- Lookup choice supports learning preferences for Visualizers and Verbalizers for vocabulary acquisition
  => Same performance
  => Different lookup pattern
  => Different access routes for retrieval
- Absence of visual information leads to lower text comprehension for Visualizers
- Overall multimedia effect for vocabulary acquisition

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Study 2

Method

- Same German Reading Text
- 2 x 2 Design (Visual and Verbal Annotations)
- Ability as Covariates
- Spatial Ability: ETS Card Rotation Test
- Verbal Ability: Nelson-Denny Reading Test
- Vocabulary test (Recognition)
- Comprehension test (Recall Protocol)
- 152 participants
Vocabulary Acquisition

- Multimedia Effect for Vocabulary Acquisition
- Main effect of verbal ability but not of spatial ability
- Main effects of the availability of verbal annotations and of visual annotations
- Two-way interaction of the availability of verbal and visual annotations

Study 2–Results (Vocabulary)

Two-way interaction (ATI) of verbal ability and the availability of visual annotations, F(1, 140) = 4.46, p = .036, η² = .031

Study 2: Vocabulary, Verbal Ability

Three-way interaction (ATI) of spatial ability, the availability of visual annotations, and the availability of verbal annotations, F(1, 140) = 12.76, p < .001, η² = .084.
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Study 2—Results (Comprehension)

Text Comprehension

- Main effects of Spatial ability and of Verbal ability
- No main effects for visual annotations, or verbal annotations

Study 2—Summary

- Visual annotations led to lower scores in vocabulary acquisition for low-ability learners
  - Insufficient cognitive resources to process visual information and build referential connections
  - Deleterious effects on vocabulary learning
- Visual annotations led to lower comprehension for all learners
  - Additional cognitive resources required to translate ambiguous visual information into verbal information

Two-way interaction of the availability of verbal and visual annotations, F(1, 137) = 5.72, p = .018, η² = .040.
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Study 2—Summary

- Forced lookup results in attention shift from text comprehension to vocabulary acquisition
- In high cognitive load situations: Only high-ability learners able to shift attention from vocabulary acquisition to text comprehension
- Overall multimedia effect for vocabulary acquisition

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Discussion

- Lookup choice
  => Supports preferences of learning with visual vs. verbal material
  => Results in equal performance but different processing patterns and retrieval cues used
- Forced lookup
  => Results in higher cognitive load for low-ability learners
  => Leads to shift of attention from text comprehension to vocabulary acquisition

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Implications

Practical Implications

- Multimedia Information is not Helpful for all Learners under all Conditions
- Instructional Application: Choice of Presentation Mode of Information Needed
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Implications

Theoretical Implications

• Importance of Study of Effect of Individual Differences in Multimedia Learning
• Support for Generative Theory of Multimedia Learning
• Cognitive Load Effects in Multimedia Learning Present for Low-Ability Learners

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Interaction Effects

• Low vs. High Knowledge (Mayer, 1997)
• Low vs. High Spatial Ability (Mayer, 1997)
• Low vs. High Spatial/Verbal Ability (Plass et al., 2003)
• Verbalizer/Visualizer Preferences (Plass et al., 1998)

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Indiv. Differences and Learning

Learning Outcome

• Can learners' characteristics be used to predict learning outcomes?
  • Need for cognition
  • Locus of Control
  • Online Course activity (Wang & Newlin, 2000)

Approach

• Prediction of success v. Design for differences
Cognitive Science Approaches to Adaptive Learning

Compensation Approach
- Compensate for shortcomings

Preference Approach
- Support Strengths

Remediation Approach
- Identify and address shortcomings

Scenario Cognitive Science

Group Discussion
You are asked to develop an adaptive learning environment for teaching the History of the Gulf War. How would you approach this project?

1. Identify relevant individual differences that affect the cognitive processes involved in instructional strategies
2. Identify their expected effect.
3. Design intervention to address this effect.

Scenario Cognitive Science

Group Activity
How can the Cognitive Theory of Multimedia Learning be used to inform the design of effective multimedia instruction? Use your own example or one of these scenarios for your answer:

- Multimedia software to improve freshmen students’ Spanish vocabulary and to support the process of reading a text in Spanish.
- Multimedia software to introduce medical students to human anatomy.
- Multimedia instruction to train experienced Airline Pilots on the navigational instruments of a new type of airplane.
- Multimedia instruction in the history of the American civil war for university students.