Designing Adaptive Testing using EEG and Eye-tracking Technology

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Three applications of computerized adaptive testing (CAT) to help solve problems encountered in educational settings are:

(a) adaptive mastery testing for determining whether or not a student has mastered a particular content area
(b) adaptive grading for assigning grades to students
(c) adaptive self-referenced testing for estimating change in a student's achievement level

Weiss & Kingsbury (2005)

Although some of the systems have adaptive testing functions, a system with a function to track students’ attention or other cognition is still not available.

(Tsai, Hou, Lai, Liu & Yang, 2012)
(A) 20 years old

(B) 70 years old

<table>
<thead>
<tr>
<th>Delta</th>
<th>Theta</th>
<th>Alpha</th>
<th>Beta</th>
<th>Gamma</th>
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<td>6.1</td>
<td>8.1</td>
<td>10.0</td>
<td>12.0</td>
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(A) 20 years old

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(A) 20 years old

(B) 70 years old
Auditory oddball event-related P300 subcomponents and clinical CASI as useful predictors of Alzheimer's disease

Task-related brain oscillations in normal aging. *Journal of Clinical Neuroscience (Revised)*.
• EEG, ERPs and Eye tracking could improve the accuracy and efficiency of testing which are supported by live-testing data.

• A system with a function to track students’ attention or other cognition will be available by using EEG, ERPs and Eye tracking technologies.
• **Neurocognition Experiment**
  - About the Laboratory
  - Equipment
  - EEG
  - ERPs
  - Eye Tracking
Electrode Cap
• Neurocognition Experiment
  ➢ About the Laboratory
  ➢ Equipment
  ➢ EEG
  ➢ ERPs
  ➢ Eye Tracking
ERPs (Event-related potentials)
Neuroscience and Education

- Neuroscience has the potential to transform our understanding of human learning and cognitive development, and therefore ultimately it has the potential to transform education.

(Goswami, 2010)
Recent Research Topics

**Interesting Topics**

- Creativity & Emotion
- Chemical Structures Learning
Through the abundance, flexibility, interactivity, and boundlessness of the Internet, the conventional linear and progressive learning method can be subverted, more creativity will be shown in web-based learning.

(Chen, Mo, & Cheng, 2006)
Negative Emotion Could Promote Creativity

(Jablow & Julian, 1998)
$\theta$ Wave
4-8 Hz

Related to Creativity
(Hudspith, 1985)

Always be found in frontal lobe
(Srinivasan, 2007)
Emotion Inducing

100ms  6s  100ms  6s
Hint  Positive Emotion  Hint  Negative Emotion
EEG Procedure & Data Collection

- Emotion Inducing by pictures and memory recalled.
- Collected EEG data with doing creativity tasks.
- Analyzed the EEG data of F3, F4, F7, F8, FZ electrodes.
Pre-test

Negative Emotion

Neutral Emotion

Positive Emotion

Post-test

Promote

ns.

ns.

θ Wave: 4-7 Hz

θ Wave: 4-7 Hz
Which brain hemisphere do you perform?

Please look at the girl. In your mind, does she rotate by clockwise or anticlockwise?

Clockwise:
right hemisphere brain
(Sense mind)

Anticlockwise:
left hemisphere brain
(Reality mind)

Both:
balance - only 14%
Implications

- The data of EEG task could develop adaptive testing of emotions or creativity on web-based learning or in e-learning environment.
The virtual chemical structural formulas need to display by computer or multimedia.
The Virtual chemical structural formulas need to display by computer or multimedia.
Electrode: PZ

rotation-related negativity

HSG

LSG
Brain activation images of 2D and 3D
Examples of Analyzed by ERPs

To identify 2D chemical structures

(A)

(B)

Implications

- By analyzing ERPs data, we could develop computer adaptive testing of 2D, 3D virtual or microcosmic chemical structural formulas. Also, the adaptive testing could classify according to the abilities of mental rotation or cognitive load.

Recent Research Topics

Interesting Topics

- Web-Based Learning vs. Cognitive Load
- Different Representations
• It is important to investigate the effects of successive and simultaneous information presentation methods on learner’s visual search ability and working memory load for different information densities. 

(Chang, Kinshuk, Chen, & Yu, 2012)

• To facilitate learners’ conceptual understanding regarding a socio-scientific issue, on-line inquiry activities may be helpful. Jonassen (1996, 2000) has argued that the Internet can be utilized as a cognitive tool to help learners acquire knowledge, and learn how to reorganize knowledge.

(Wu & Tsai, 2011)
High Achievement Students

Low Achievement Students

The analysis of data from Eye Tracking could provide the distribution of students’ attention in web-based learning.
Recent Research Topics

Interesting Topics

- Web-Based Learning vs. Cognitive Load
- Different Representations
To investigate which strategy students used to solve problems, the numbers of fixation were analyzed with correlation statistics.

Shifting of AOI was defined as six directions of fixating the picture. (D1~D6)
Scan path analysis

<table>
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<th>Stages</th>
<th>Rep. types</th>
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Explore the influence of prior knowledge on understanding in scientific figure through eye tracking. *Bulletin of Educational Psychology, 43*(2), 24-46 (2011)
Interesting Combination of Analysis

1. Cooperating with New York University (Ken Tobin)  
   (pilot study by Chia Ju Liu & Ken Tobin)

2. Cooperating with Cambridge University (Denes)
• p125

Chia Ju Liu’s study aligns with research on mindfulness, which Kirk Warren Brown, Richard Ryan, and J. David Creswell (2007, p. 212) defined as “receptive attention to and awareness of present events and experience.”

• p126

After giving some thought to ways in which our research might be informed by neural level analyses we collaborated with Liu and her Taiwanese colleagues in a study that examined reflexive practices involved with learning to teach. As he reviewed a selected vignette on a computer, an electroencephalographic (EEG) analysis was undertaken and infrared techniques were used to track his eye movements.

(Ken Tobin, 2011)
• At the moment Amanda utters Westchester F0 is 172.8 Hz in 9.84ms.
There were 5 fixation points and the fixation duration in each point was varied. The circle No. 8 was the start of eye tracking. The circle No. 12 was the fixation point at 9.800s.
Interesting Combination of Analysis

1. Cooperating with New York University (Ken Tobin)  
   (pilot study by Chia Ju Liu & Ken Tobin)

2. Cooperating with Cambridge University (Denes)
Participants (n=83):

First-grade students (Mean age ± S.D.: 7.3 ± 0.8 years)
Third-grade students (Mean age ± S.D.: 9.6 ± 1.3 years)
Fifth-grade students (Mean age ± S.D.: 11.6 ± 0.8 years)

First-grade students

Third-grade students

Fifth-grade students
(A) The early component (80 – 140 ms)

<table>
<thead>
<tr>
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<th>Theta</th>
<th>Alpha-1</th>
<th>Alpha-2</th>
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(B) The late component (280 – 450 ms)

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Combined ERPs & Eye Tracking
Thank You

Chia-Ju Liu

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