Teaching Perceptual Skills in Clinical Diagnosis Using Digital Media

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Visual Diagnosis for Static Stimuli

Step 1: Task Analysis Using Eye Tracking

**eye-mind assumption**
(Just & Carpenter, 1993)

Gegenfurtner, 2011;
Scheiter & van Gog, 2009;
van Gog & Scheiter, 2010
MEDICAL IMAGE

GLOBAL IMPRESSION

FOCAL ANALYSIS
search perturbed regions

OBJECT RECOGNITION

visual scrutiny test for abnormal features

DECISION MAKING

Positive fit

visual dwell

Negative fit

Nodine & Mello-Thoms (2000)
Visual Diagnosis: An Error-prone Process

• 30% miss rate and an equally high false positive rate (Krupinski, 2010)

• error classification (Kundel, Nodine, & Carmody, 1978)
  • search errors: not attending to relevant feature
  • recognition errors: attending to relevant feature shorter than necessary to detect feature
  • decision errors: failure in interpreting attended features correctly / dismissing features as being irrelevant

Visual Diagnosis Based on Dynamic Real-World Observations
Task Demands in Processing Dynamic Input

- **focusing visual attention** on relevant information over time
  - occlusions, blurriness
  - transience
  - parallel events (shifting attention between features)

- **avoiding distraction** due to salient, but irrelevant information
  - color, size, shape etc.
  - movement

- **integrating visual information** across time and space

- **interpreting** information / decision making

Overview

• Goal: Develop instructional method to teach students how to **process dynamic visual input**

• Step 1: **Task analysis** to determine task demands
  • How do experts process dynamic visual input?
  • What are difficulties of novices regarding this task?

• Step 2: Development of an **instructional method**
  • results from task analysis
  • state-of-the-art: cognitive skill acquisition
  • innovative use of technology

• Step 3: **Empirical evaluation**
### Task Analysis: Procedure, Knowledge, & Skills

| 1. Specifying *body parts* that might be affected by the disease | **Visual search** and **identification** of uncommonly moving body parts |
| 2. Specifying the *motion pattern* of these body parts | **Visual inspection** of suspected body parts and **interpretation** of their motion |
| 3. Specifying infant’s state of *consciousness* | **Visually inspecting** and **interpreting** facial indicators for consciousness |
| 4. Indicating the involvement of the *face* | **Visual search** and **identification** of uncommon motion or lack of it within the face |
| 5. Indicating a *change* in motion after touching | **Visual search** and **identification** of change in motion |
| 6. *Diagnosis* of the disease | **Assignment** of observations to the corresponding diagnostic code |

### Diagnostic system:
International League Against Epilepsy, 2010

### Differential diagnosis:
Egger et al., 2003; Hansen & Balslev, 2009
### Perceptual Skills

**(Chi, 2006; Manning et al., 2005)**

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Based on perceptual input, i.e., **perceptual skills**

Based on conceptual knowledge
Step 2: Develop Instructional Method - Choice of Materials?

- **verbal guidance?** (i.e., systematic approach to scanning image; Kundel, 2000)

- reduce complexity of input?

- provide (attentional) guidance for processing complex input?
Step 2: Develop Instructional Method - Choice of Materials?

- verbal explanations?

- **reduce complexity of input?** (e.g., increasing contrast, color coding; Krupinski, 2000)

- provide (attentional) guidance for processing complex input?
Benefits of Schematized Graphics for Teaching Conceptual Understanding

- Schematizing dynamic visualizations illustrating mitosis

- Dependent variables
  - Understanding of functions and processes (verbal)
  - Error detection, drawing components, sorting phases (pictorial)

Scheiter et al. (2009), *Learning and Instruction*
Step 2: Develop Instructional Method - Choice of Materials?

• verbal explanations?

• reduce complexity of input?

• provide (attentional) guidance for processing complex input?
Benefits of Cueing Information in (Complex) Graphics

- series of static pictures illustrating functioning of the heart

- results
  - cueing improves understanding and guides visual attention
  - changes in visual attention explain effect on learning outcomes

Scheiter & Eitel (2010), *Diagrams*
Consequences

- **Cueing** = suitable method to guide visual attention and teach understanding (Kundel, Nodine, Lauver, & Toto, 1997; Krupinski, Nodele, & Kundele, 1993; Litchfield, Ball, Donovan, Manning, & Crawford, 2010)

- **Difficulties** regarding dynamic, real-world phenomena
  - design of cues
    - when to look where? (timing and location of cues)
    - order of processing information? (order of cues)
  - learning goals: understanding (end product) versus perceptual skills (process)

- **Consequences** for developing instructional method
  - use expert behavior to inform cue design
  - focus on skill acquisition
learning by **observing a model** during performing a task (Bandura, 1977)

**Cognitive apprenticeship**
(Collins, Brown, & Newman, 1989)
“modeling” *cognitive* processes, i.e., not directly observable processes:

Model verbalizes her/his internal states.

**Replay expert gaze behavior to novices**
(Augustyniak & Tadeusiewicz, 2006; Krupinski et al., 2006; Wilson et al., 2010)


EMMEs improve detection of nodules in chest X-rays (Litchfield et al., 2010)

Does this also work for dynamic stimuli?

Do EMMEs aid development of perceptual skills?

How to design EMMEs?
**Step 3: Empirical Evaluation**

N = 60 medical students in their final year

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**Eye movement modeling examples during learning**

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<tr>
<th>Control</th>
<th>Circle display</th>
<th>Spotlight display</th>
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<td>n = 20</td>
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Jarodzka et al. (submitted), *Instructional Science*
Learning Phase: Attentional Guidance

Two single infants aged 3 weeks and 7 months; prototypical cases of epilepsy

"Please take a look at the way the infant behaves."

3 Items
17-50 sec

Which body parts are affected by the disease?
How do these body parts move?
Do the movements change after touching the infant?
Is the face diseased?
What is the infant’s level of consciousness?

RIME 2011
Two single infants aged 3 weeks and 7 months; prototypical cases of epilepsy

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“Please take a look at the way the infant behaves.”

Which body parts are affected by the disease?
Research Questions

1. Does EMME guide the students’ attention?
2. Does EMME lead to a more efficient visual search?
3. Does EMME lead to a better interpretation performance?
1. Does EMME *guide* the students’ *attention*?

Euclidean distance over time between model’s and student’s gaze points

$F(2,57) = 4.40, p = .02$
2. Does EMME lead to a more efficient visual search?

Time until looking at and dwell time on relevant areas:

\[ F(2,57) = 4.06, p = .02 \]

\[ F(2,57) = 3.64, p = .03 \]
3. Does **EMME** lead to a better *interpretation* performance?

multiple-choice questionnaire on detecting and interpreting features

\[ F(2,57) = 3.53, \ p = .04 \]
The Benefits of Spotlight EMMEs

- **successful attention guidance** (smaller Euclidean distance between expert’s and student’s gaze points)

- **more efficient visual search** and **prolonged visual inspection** (faster orientation towards relevant information and more intensive processing of it)

- **better interpretation performance**

- **reducing complexity** more successful than adding information
Conclusions

- **generalization**: EMME successful in teaching perceptual skills ... also in domains other than medical diagnosis
  - biological classification task (Jarodzka et al., submitted)
  - problem solving (Lichtfield & Ball, 2011)

- positive effect after very **short training**

- currently developed as off-line training, but has potential for **online training**

- **open issues**
  - level of expertise concerning model?
  - role of parafoveal processing? fading of blurring necessary with developing expertise? (cf.Krupinski, 2010; Kundel, Nodine, Conant, & Weinstein, 2007; Reingold, Charness, Pomplun, & Stampe, 2001)
  - additional support for decision making necessary? (Manning et al., 2004)
Thanks for Your Attention!

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Kenneth Holmqvist, Marcus Nyström

Thomas Balslev, Berit Eika

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RIME 2011