Learning to See: Role and Teaching of Perceptual Skills

Dr. Halszka Jarodzka

Keynote

ICO National Fall School

3rd November 2011
Let me introduce myself...

- 2007: Masters in Psychology in EKU Tuebingen, Germany
  - Master thesis: how to overcome the information exchange dilemma via shared databases (implemented as a web-based computer game)

- 2007-2010: Research scientist and Ph.D. candidate at the KMRC
  - Ph.D. thesis: characteristics and training of visual expertise investigated via eye tracking and verbal reports
  - Research stays in Sweden (ETLab), Denmark (medical department), and the Netherlands (OU)

- Since July 2010: Assistant professor at the CELSTEC, OU

- Research interests
  - Basic eye tracking research: scanpath similarity measure, co-author of book on eye tracking methodology
  - Applied eye tracking research on expertise differences, EMME, mental effort, web search, etc.
What are perceptual skills and when do we need them?
Tasks related to complex and dynamic perceptual input (i.e., visualizations)

- air traffic control
- car traffic
- meterology
- biodiversity
- medical diagnosis
Project on conveying the classification of fish locomotion patterns

These visualizations depict the same content (fish locomotion patterns), have the same function (conveying knowledge on f.l.p.), but still differ dramatically! And hence, so did their effects:

e.g., Imhof, Scheiter, Edelmann, Von Ulardt, & Gerjets, 2011; Imhof, Scheiter, & Gerjets, 2011; Jarodzka, Scheiter, Gerjets, Van Gog, & Dorr, 2009; Kühl, Scheiter, Gerjets, & Edelmann, 2011; Kühl, Scheiter, Gerjets, & Gemballa, 2011; Pfeiffer, Gemballa, Jarodzka, Scheiter, & Gerjets, 2009
Detailed classification system of visualizations

Components

- **Function**: complementary, attention controlling, working memory offloading, long-term memory supporting, affective
- **Content**: domain, genre, coherence, immersiveness, target group, type of conveyed knowledge, realism of content, ...
- **Structural features**: dynamism, realism, interactivity, accompanying text/audio, cueing, visualization type, ...

Potential benefits:

- Identify moderators in processing visualizations
- Reveal lack in research on certain visualization types
- Unravel the degree of impact of the dimensions on learning
Imhof, Jarodzka, & Gerjets, 2009. Journal of Interdisciplinary Image Science

Detailed classification system of visualizations

Components

- **Function**: complementary, attention controlling, working memory offloading, long-term memory supporting, affective

- **Content**: domain, genre, coherence, immersiveness, target group, type of conveyed knowledge, realism of content, ...

- **Structural features**: dynamism, realism, interactivity, accompanying text / audio, cueing, visualization type, ...

Potential benefits:

- Identify moderators in processing visualizations
- Reveal lack in research on certain visualization types
- Unravel the degree of impact of the dimensions on learning
Difficulties in cognitively processing ... (Atkinson & Shiffrin, 1971; Mayer 2005)

...complex / realistic visualizations (e.g., Dwyer, 1976; Schnottz & Lowe, 2008)
  • Large amount of information, a lot of it is irrelevant
  • Relation of thematic relevance and visual saliency often not optimal
  \(\rightarrow\) challenging to **select** relevant information

...dynamic visualizations (e.g., Lowe, 2003; Hegary, 1992)
  • (Relevant) info is transient
  • Simultaneous appearance of information (split attention)
  \(\rightarrow\) challenging to keep information active so that it can be **integrated**
Example: Perceptual skills in biological classification
Example: Perceptual skills in medical diagnosis
Perceptual challenges of both tasks

**Biological classification**

Realism
- Much *irrelevant* information present
- *Visual salient* information is not always thematically relevant, however, thematic relevant information is always salient

Dynamism *(Lowe, 2003; 2004)*
- Transformations
- Translations
- No transitions

**Medical diagnosis**

Realism
- Much *irrelevant* information present
- *Visual salient* information is not related to thematic relevance

Dynamism *(Lowe, 2003; 2004)*
- Transformations
- Translations
- Transitions
**Perceptual skills** (Bass & Chiles, 1990; Chi, 2006; Krupinski, 2010; Manning et al., 2005; Nodine & Krupinski, 1998)

<table>
<thead>
<tr>
<th>Based on <strong>perceptual input</strong>, i.e., perceptual skills</th>
<th>Based on <strong>conceptual knowledge</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visual search</strong> and identification of relevant elements</td>
<td><strong>Assignment of observations to according class / diagnosis</strong></td>
</tr>
<tr>
<td>Visual inspection and <strong>interpretation</strong> of relevant elements</td>
<td><strong>Classification of the locomotion pattern</strong></td>
</tr>
<tr>
<td>Specifying <strong>body parts</strong> that are used to produce propulsion</td>
<td><strong>Diagnosis</strong> of the disease</td>
</tr>
<tr>
<td>Specifying <strong>motion pattern</strong> of these body parts</td>
<td>Specifying <strong>motion pattern</strong> of these body parts</td>
</tr>
</tbody>
</table>
Research questions

1. Analyzing the role of perceptual skills on different expertise levels.

2. Developing and testing a method to teach perceptual skills.
Investigating the role of perceptual skills with increasing expertise
Overview: empirical findings on expertise differences in perceptual tasks

- **Performance**: Experts execute tasks better and faster (e.g., De Groot, 1946/1978; Reingold & Charness, 2005)

But, not the mere performance is interesting, but rather the underlying **processes** that cause this performance advantage (Edwards, 1992; Ericsson & Lehmann, 1996; Sternberg & Frensch, 1992)

- **Experts** look **faster and longer** on relevant areas on the images (e.g., Canham & Hegarty, 2010; Charness et al., 2001; Haider & Frensch, 1999; Underwood et al., 2003).

... but this is **very rough** (strategies?) and hardly any research of perceptual processes in **dynamic** visualizations, yet!
Investigating perceptual skills by means of eye tracking

**Eye tracking:** Tracking the movements of the eyeball(s) to learn **where** a person looked, for how **long**, and in what **order**.
Eye tracking data does tell us where a participant was looking at but not why.

**Methodological triangulation** with other data sources, like *verbal reports* and *performance* data.
Exemplary set-up

- Eye tracker
- Flat microphone
- Stimulus presentation
- Performance response
Exemplary procedure

1. “Please take a look at the way the fish swims.”

2. Description of the locomotion pattern

3. “Please watch the replay and tell me what you were thinking during your first viewing.”

(Van Gog, Paas, Van Merriënboer, & Witte, 2005)

Eye movements

Performance

Cued retrospective reports
Analysis of the role of perceptual skills in diverse domains

- ... in classifying biological locomotion patterns.
  Jarodzka, Scheiter, Gerjets, & Van Gog (2010). *Learning and Instruction*

- ... in diagnosing epileptic seizures in infants.

- ... in controlling air traffic.
  Van Meeuwen, Jarodzka, Brand-Gruwel, Van Merriënboer, De Bock, & Kirschner (in prep)
Empirical findings on the role of perceptual skills in domain-specific expertise

- Improving perceptual skills required for dynamic stimuli
  - efficient visually search within (equally) salient relevant and irrelevant elements and detection of relevant elements
  - correct interpretation of (the motion of) these elements
    (cf. Antes & Kristjanson, 1991; Canham & Hegarty, 2010)

- Expert-specific strategies (*fish only*) (cf. Boshuizen & Schmidt, 1992)
  - Knowledge- and experience-based shortcuts increase with expertise & enable a fast and correct reaction
  - found in verbal and in eye tracking data
  - strategies become more diverse with increasing expertise (as measured by string-editing Levenshtein method of scanpaths) (cf. Medin, Ross, Atran, Cox, Coley, Proffitt, et al., 2006)
Current projects on visual expertise in medicine

Two scenarios

Diagnosing *dynamic* ultrasound videos of foetuses

Diagnosing *interactive* histological slides

Jarodzka, Jaarsma, Holmqvist, & Boshuizen

Jaarsma, Jarodzka, Boshuizen, & Van Merriënboer
Conclusions and future directions

• Many professions / real-world tasks are perceptual tasks, hence, they are bound to a visualization, like car driving, medical diagnosis, etc. (Chi, 2006)

• Visualizations differ dramatically in their functions, contents, and structural features and so does research on them (Imhof, Jarodzka, & Gerjets, 2009)

• For instance, eye tracking research on dynamic visualizations is underrepresented, exceptions: Balslev, Jarodzka et al. 2011; Jarodzka et al., 2010 (in Vision Science upcoming line of research: perception of dynamic scenes)

• Such tasks require perceptual skills, i.e., the detection and interpretation of relevant elements, which dramatically differs across expertise levels.

• Hence, no theories on this visual expertise exist, yet.
1st approach to a model on visual expertise in the example of medicine

Incorporation of theories on **memory structures** (Atkinson & Shiffrin), **medical expertise** (Lesgold et al., Schmidt & Boshuizen), and **eye tracking** research (Jarodzka, Krupinski)
Training perceptual skills via EMME
Conveying Perceptual Skills

No methods to convey perceptual skills, the development of this inspired by methods to teach cognitive skills.

A prototypical instructional method for initial skill acquisition is example-based learning (cf. Van Gog & Rummel, 2010; Renkl, i.p.), like

Worked examples (e.g., Sweller, Van Merriënboer & Paas, 1998)

"modeling" processes that are not directly observable, like cognitive processes:


HOWEVER:
Only cognitive skills were modeled so far (reading, writing, calculating,...).

We need to model perceptual skills!
Novel instructional approach: Eye movement modeling examples

Moreover: Dorr, Jarodzka, & Barth, 2010; Jarodzka, Scheiter, Gerjets, Van Gog, & Dorr, 2009; Jarodzka, Balslev, Holmqvist, Nyström, Scheiter, Gerjets, & Eika, 2010;
First implementation of EMME in a procedural task
First implementation of EMME in a procedural task

→ EMME were *detrimental* for learning

**WHY?**

• **Redundancy** of eye movements? Easy to infer from verbalizations where to look at? More complex task, where the learners would not know to which element the model refers to! → fish & babies!

**OR**

• Eye movement display *adds too much noise* (fixations) to an already rich stimulus? → other forms of eye movement display design?
Solution: Presentation of perceptual processes in video examples

- **Adding** information on perceptual processes to complex visualizations: overload (e.g., Chandler & Sweller, 1991; Mayer, 2001) ➔ **Dot / Circle**

- Presenting perceptual processes by **reducing** existing information (Dorr, Vig, Gegenfurtner, Martinetz, & Barth, 2008; Itti & Koch, 2000; Nyström & Holmqvist, 2008) ➔ **Spotlight**
Design

N = 60 medical students in their final year

<table>
<thead>
<tr>
<th></th>
<th>Control (none)</th>
<th>Circle display</th>
<th>Spotlight display</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n = 20</strong></td>
<td>n = 20</td>
<td>n = 20</td>
<td>n = 20</td>
</tr>
</tbody>
</table>

Eye movement modeling examples during learning
Research questions

During **learning**:

1. Does EMME **guide** the students’ attention?

During **testing**:

2. Does EMME lead to a more efficient **visual search**?

3. Does EMME lead to a better **interpretation** performance?
**Procedure**

**Learning**

EMME (no vs. dot vs. foveation)

• Does **EMME guide** the students’ attention?

**Testing**

New videos without guidance

• Does **EMME** lead to a more efficient **visual search**?

• Does **EMME** lead to a better **interpretation** performance?

SMI High Speed 240 Hz
EMME implemented in different domains

- leapfrog flash game

- classifying locomotion patterns of reef fish

- diagnosing epileptic seizures in infants
EMME in biological classification – Results

Effect of both designs:

1. Successful attention guidance: learners follow the model’s gaze
   spotlight display < dor display < control group

Differential effect:

2. More efficient visual search: looking faster and longer on relevant
   features
   spotlight display < other two groups

3. Better interpretation performance: higher MCQ scores
   dot display > other two groups
Consequences for following study

1. Increasing the **complexity** of the task
   - **Visual search**: relevant information is transient & not salient
   - **Interpretation**: Underlying decision tree includes more steps

   → Epileptic seizures in pediatric neurology

2. Optimizing the **design** of eye movement display:
   - **Spotlight** more subtle: holistic perception of scene possible
   - Dot → **Circle**, as the relevant elements are so small that they would be covered by a dot
EMME in medical diagnosis – Results

1. Successful attention guidance: closer to model’s gaze
   spotlight display < other two groups

2. More efficient visual search: looking faster and longer on relevant features
   spotlight display > other two groups

3. Better interpretation performance: higher MCQ scores
   spotlight display > other two groups
### Summary of results (compared to control group without cue)

<table>
<thead>
<tr>
<th>Task</th>
<th>Problem Solving</th>
<th>Biological Classification</th>
<th>Medical Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceptual complexity</td>
<td>low</td>
<td>high</td>
<td>very high</td>
</tr>
</tbody>
</table>

**Design**

<table>
<thead>
<tr>
<th>Attention guidance</th>
<th><img src="image1.png" alt="Visual Search" /></th>
<th><img src="image2.png" alt="Visual Search" /></th>
<th><img src="image3.png" alt="Visual Search" /></th>
<th><img src="image4.png" alt="Visual Search" /></th>
<th><img src="image5.png" alt="Visual Search" /></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Visual Search" /></td>
<td><img src="image2.png" alt="Visual Search" /></td>
<td><img src="image3.png" alt="Visual Search" /></td>
<td><img src="image4.png" alt="Visual Search" /></td>
<td><img src="image5.png" alt="Visual Search" /></td>
<td><img src="image6.png" alt="Visual Search" /></td>
</tr>
<tr>
<td><img src="image1.png" alt="Visual Search" /></td>
<td><img src="image2.png" alt="Visual Search" /></td>
<td><img src="image3.png" alt="Visual Search" /></td>
<td><img src="image4.png" alt="Visual Search" /></td>
<td><img src="image5.png" alt="Visual Search" /></td>
<td><img src="image6.png" alt="Visual Search" /></td>
</tr>
<tr>
<td><img src="image1.png" alt="Visual Search" /></td>
<td><img src="image2.png" alt="Visual Search" /></td>
<td><img src="image3.png" alt="Visual Search" /></td>
<td><img src="image4.png" alt="Visual Search" /></td>
<td><img src="image5.png" alt="Visual Search" /></td>
<td><img src="image6.png" alt="Visual Search" /></td>
</tr>
<tr>
<td><img src="image1.png" alt="Visual Search" /></td>
<td><img src="image2.png" alt="Visual Search" /></td>
<td><img src="image3.png" alt="Visual Search" /></td>
<td><img src="image4.png" alt="Visual Search" /></td>
<td><img src="image5.png" alt="Visual Search" /></td>
<td><img src="image6.png" alt="Visual Search" /></td>
</tr>
<tr>
<td><img src="image1.png" alt="Visual Search" /></td>
<td><img src="image2.png" alt="Visual Search" /></td>
<td><img src="image3.png" alt="Visual Search" /></td>
<td><img src="image4.png" alt="Visual Search" /></td>
<td><img src="image5.png" alt="Visual Search" /></td>
<td><img src="image6.png" alt="Visual Search" /></td>
</tr>
</tbody>
</table>

- ![Visual Search](image1.png) indicates an increase.
- ![Visual Search](image2.png) indicates a decrease.
- ![Visual Search](image3.png) indicates no change.
- ![Visual Search](image4.png) indicates an unknown change.
- ![Visual Search](image5.png) indicates a negative effect.
- ![Visual Search](image6.png) indicates a positive effect.

**Notes:**
- ?, [↓] indicate uncertainty or direction of change.
- × indicates no effect or no change.
- ↑ indicates improvement or increase.
- ↓ indicates deterioration or decrease.

*Images depict visual stimuli and responses related to the tasks.*
What I wanted to convince you about today:

- Many tasks are perceptual tasks
- It is worth to have a closer look at the accompanying perceptual skills and how they develop with expertise
- When doing so, carefully consider what characterizes the visualizations you use (take dynamic ones ;-))
- Try to incorporate your findings into existing theories!
- Conveying perceptual skills is possible! By means of EMME or ...?
Thank you for your eye movements!

Halszka.Jarodzka@OU.nl