Learning to See:
Role and Teaching of Perceptual Skills

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Keynote

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Centre for Learning Sciences and Technologies

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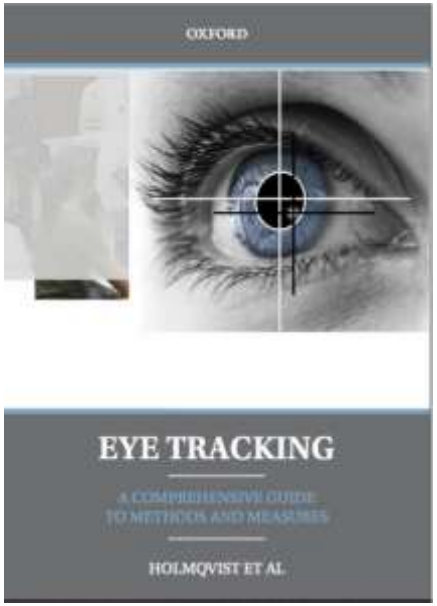
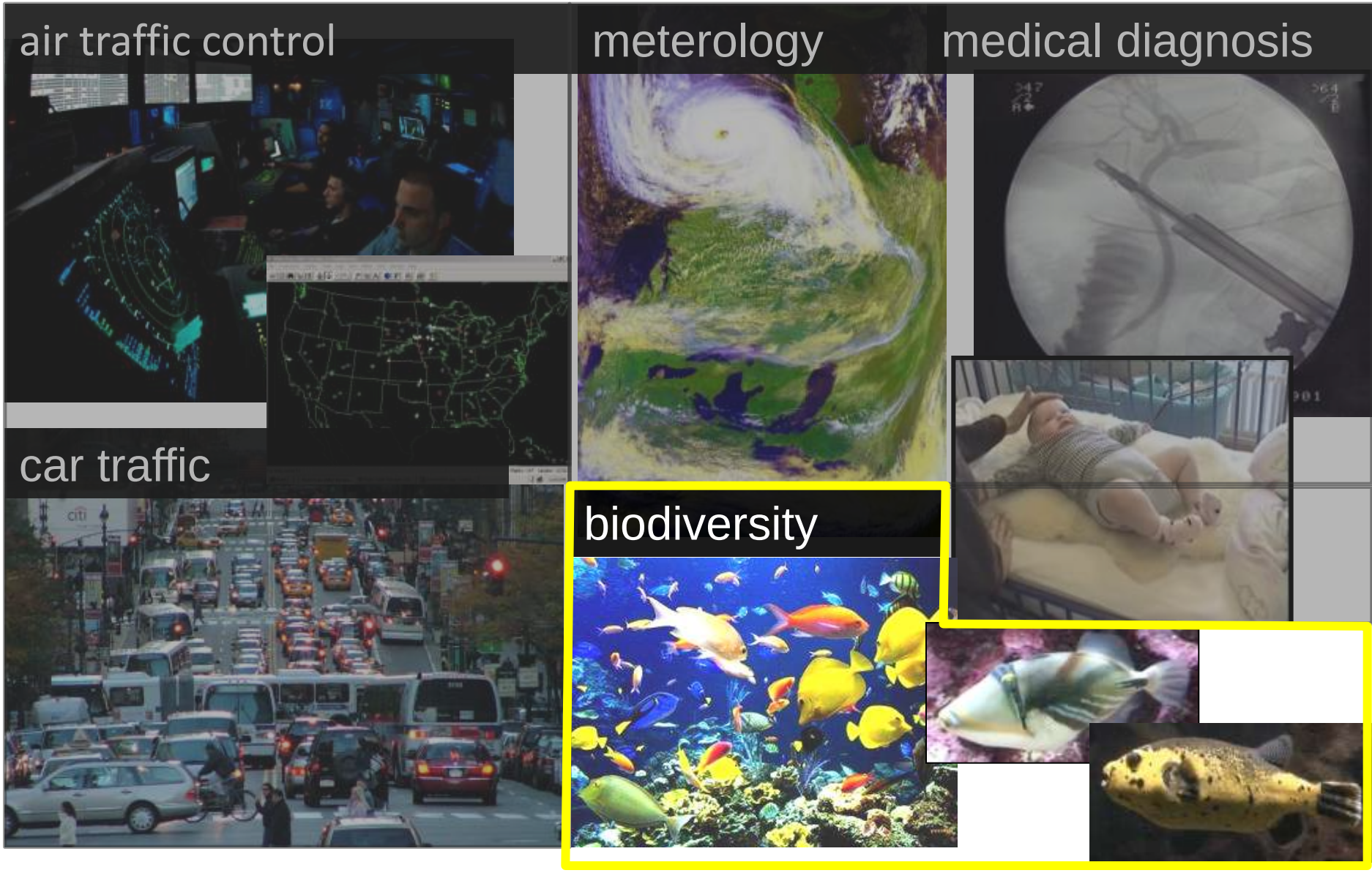
Let me introduce myself…

- 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?

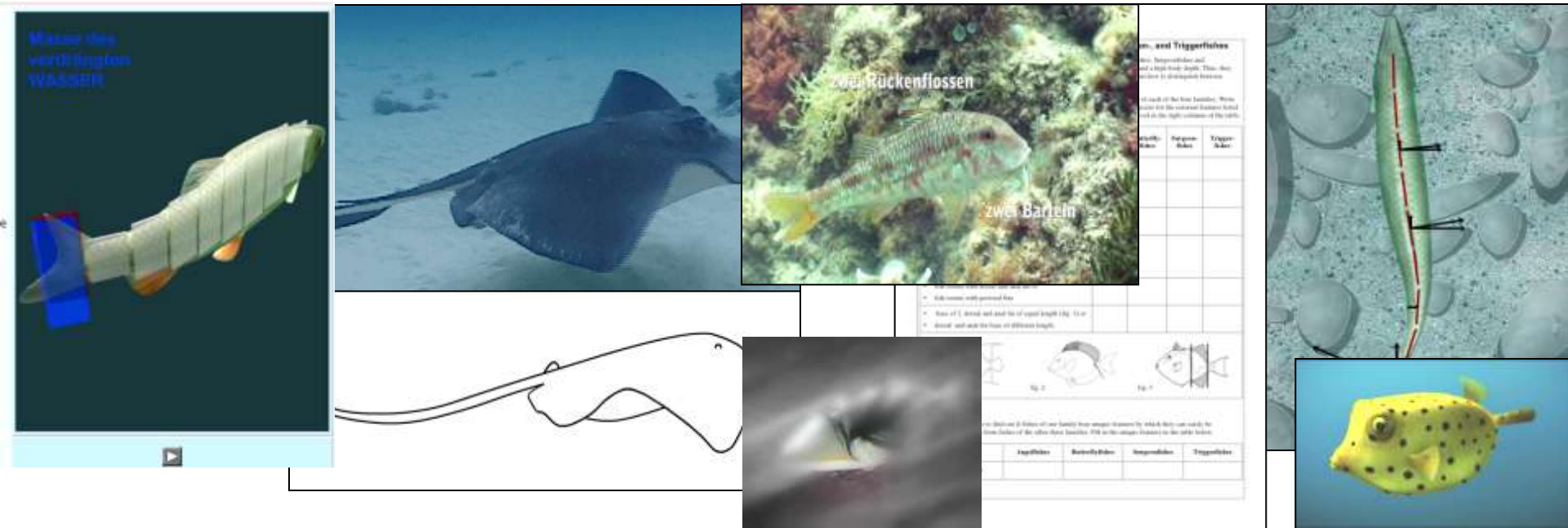
Tasks related to complex and dynamic perceptual input (i.e., visualizations)



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



Imhof, Jarodzka, & Gerjets, 2009. *Journal of Interdisciplinary Image Science*

Detailed classification system of visualiztions

Components

- **Function**: complementary, attention controlling, working memory offloading, long-term memory supporting, affective
- **Content**: domain, genre, coherence, immersiveness, target group, type of conveyed knowledge, realsim 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*

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Difficulties in cognitively processing … (Atkinson & Shiffrin, 1971; Mayer 2005)

…complex / **realistic** visualizations (e.g., Dwyer, 1976; Schnotz & Lowe, 2008)

- Large amount of information, a lot of it is irrelevant
- Relation of thematic relevance and visual saliency often not optimal

→challenging to **select** relevant information

…**dynamic** visualizations (e.g., Lowe, 2003; Hegary, 1992)

- (Relevant) info is transient
- Simultaneous appearance of information (split attention)

→ 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)

			
Based on **perceptual input**, i.e., perceptual skills	**Visual search** and identification of relevant elements	Specifying *body parts* that are used to produce propulsion	Specifying *body parts* that might be affected by the disease
	Visual inspection and **interpretation** of relevant elements	Specifying *motion pattern* of these body parts	Specifying *motion pattern* of these body parts
Based on **conceptual** knowledge	**Assignment** of observations to according class / diagnosis	*Classification* of the locomotion pattern	*Diagnosis* of the disease

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

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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)

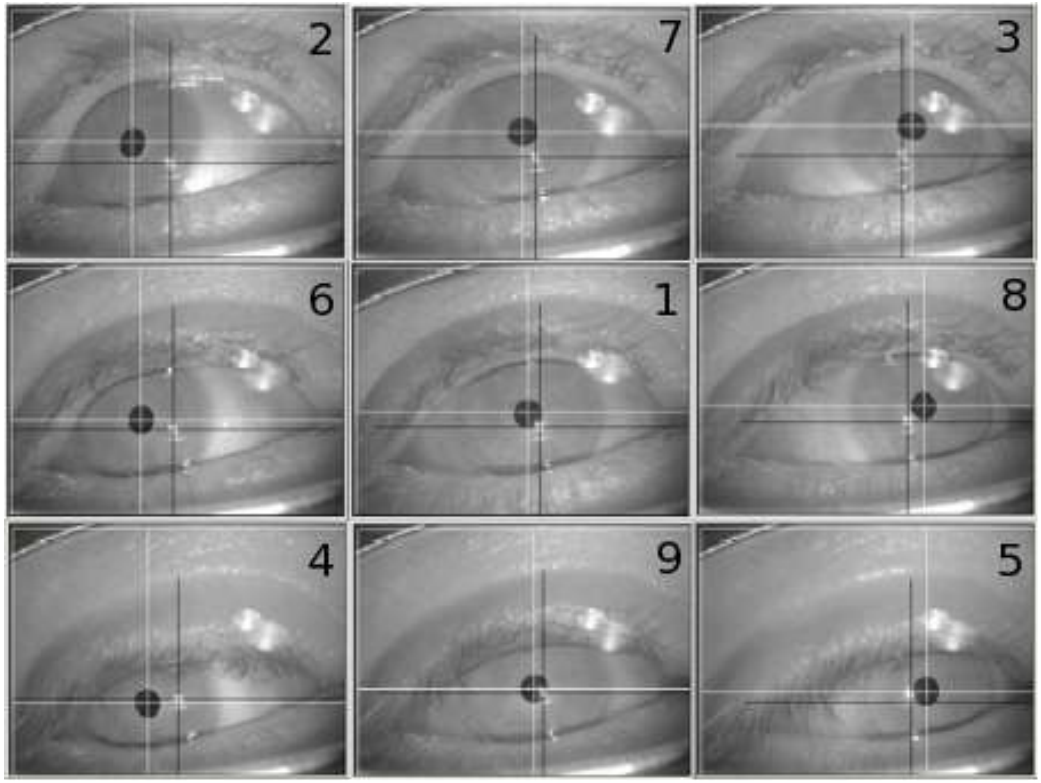
- Experts look **faster and longer** on relevant areas on the images (e.g., Canham & Hegarty, 2010; Charness et al., 2001; Haider & Frensch, 1999; Underwood et al., 2003).

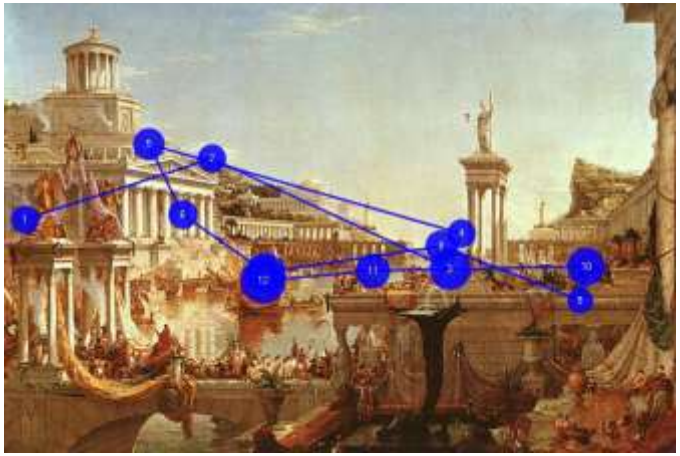
... but this is **very rough** (strategies?) and hardly any research of perceptual processes in **dynamic** visualizations, yet!

Holmqvist, Nyström, Andersson, Dewhurst, Jarodzka, & van de Weijer, 2011. *Oxford University Press*

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**.



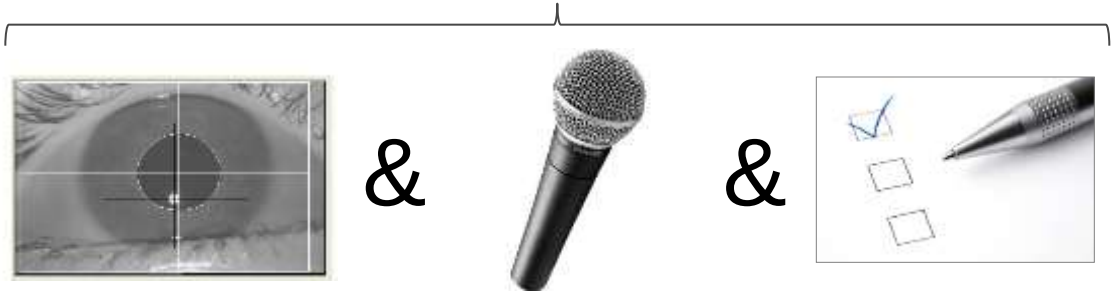


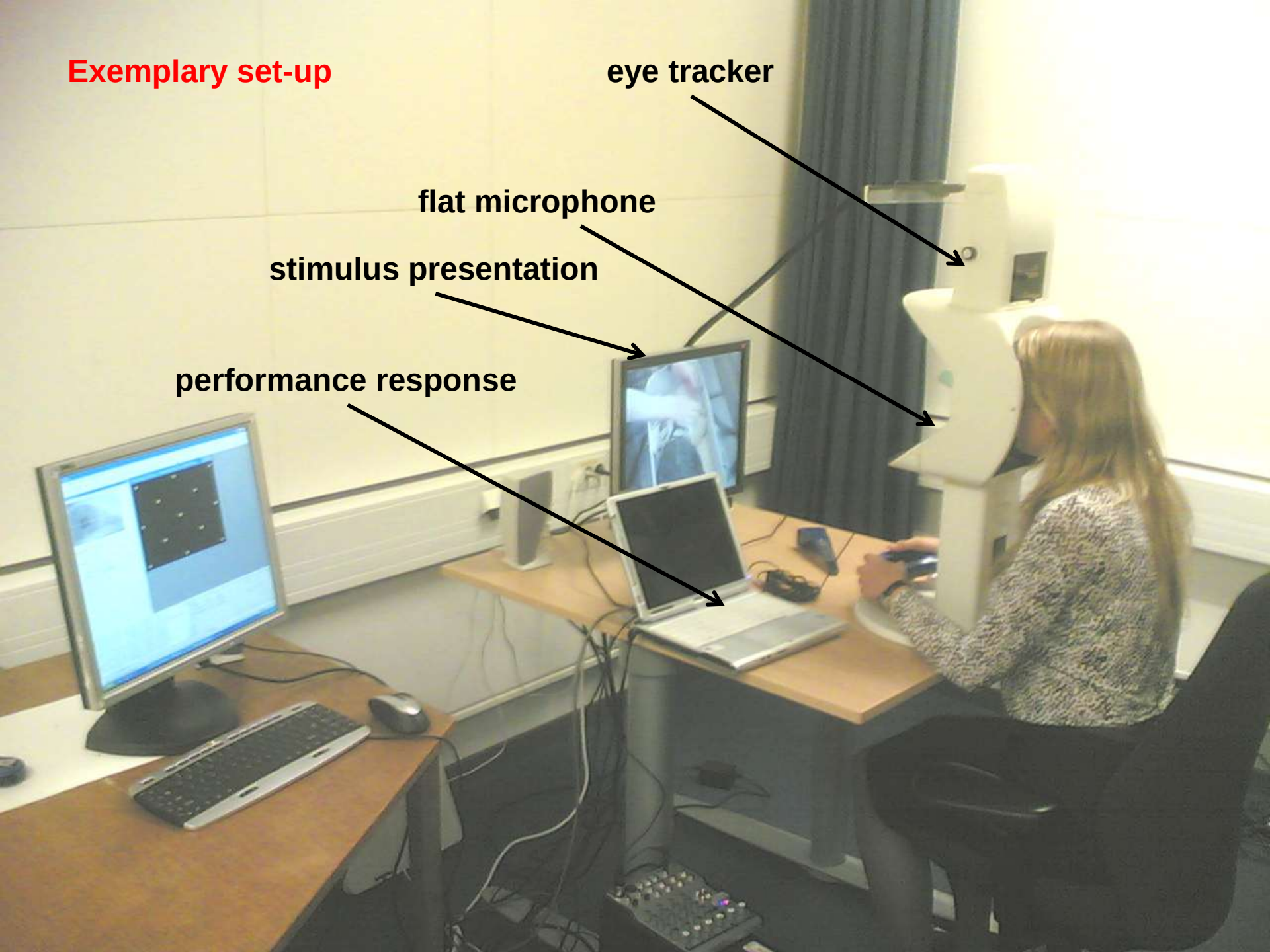
Holmqvist, Nyström, Andersson, Dewhurst, Jarodzka, & van de Weijer, 2011. *Oxford University Press*

Investigating perceptual skills by means of methodological triangulation

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.

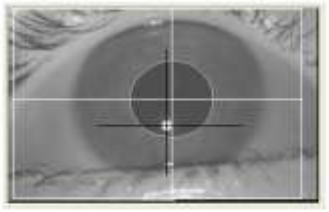



Exemplary set-up
eye tracker
flat microphone
stimulus presentation
performance response

Exemplary procedure

1. *"Please take a look at the way the fish swims."*

measures



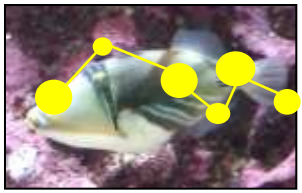
Eye movements

2. Description of the locomotion pattern

Performance

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

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



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.

Balslev, Jarodzka, Holmqvist, De Grave, Muijtjens, Eika, Van Merriënboer, & Scherpbier (2011). *European Journal of Paediatric Neurology*

- … 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)

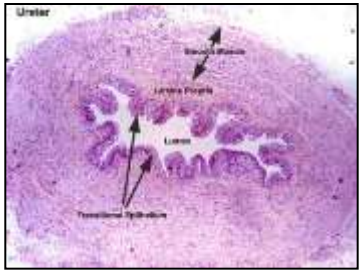
Current projects on visual expertise in medicine

Two scenarios

Diagnosing ***dynamic*** ultrasound videos of foetuses

Jarodzka, Jaarsma, Holmqvist, & Boshuizen

Diagnosing ***interactive*** histological slides



Jaarsma, Jarodzka, Boshuizen, & Van Merriënboer

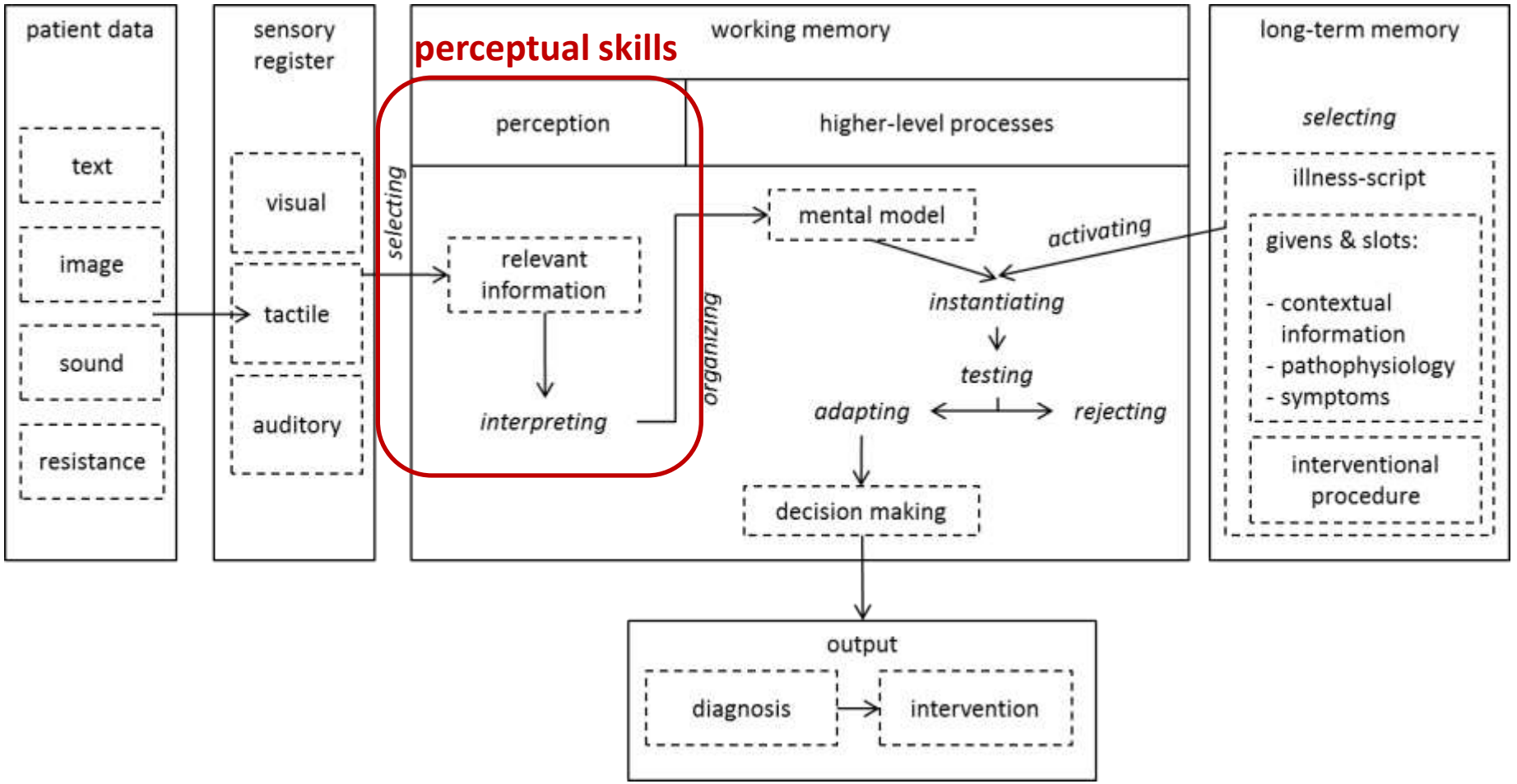
Conclusions and future directions

- 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 scene*s)
- 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.

Jarodzka, Boshuizen, & Kirschner, subm.

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

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Conveying Perceptual Skills

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

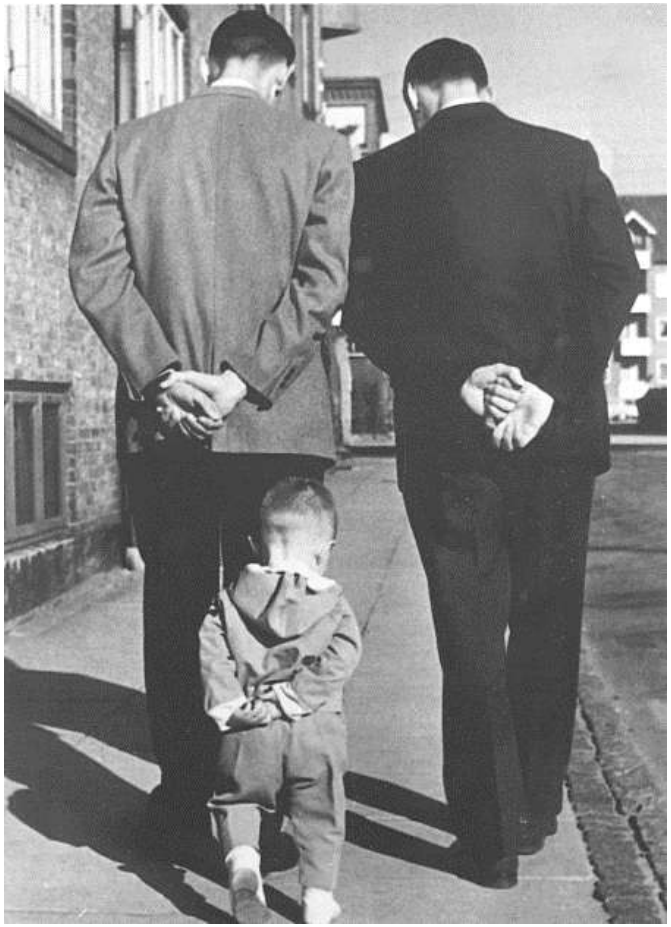
A prototypical instructional method for initial skill acquisition is example-based learning (cf. Van Gog & Rummel, 2010; Renkl, i.p.), like

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

Cognitive modeling (Bandura, 1977; Collins, Brown & Newman, 1989)

Instructional Approach: Example-based learning

Learning by observing a model during task performance (e.g.,. Bandura, 1977).



Learning by studying examples of successful task performance is more efficient than learning by problem-solving alone (Kirschner, Sweller, & Clark, 2006).

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

...

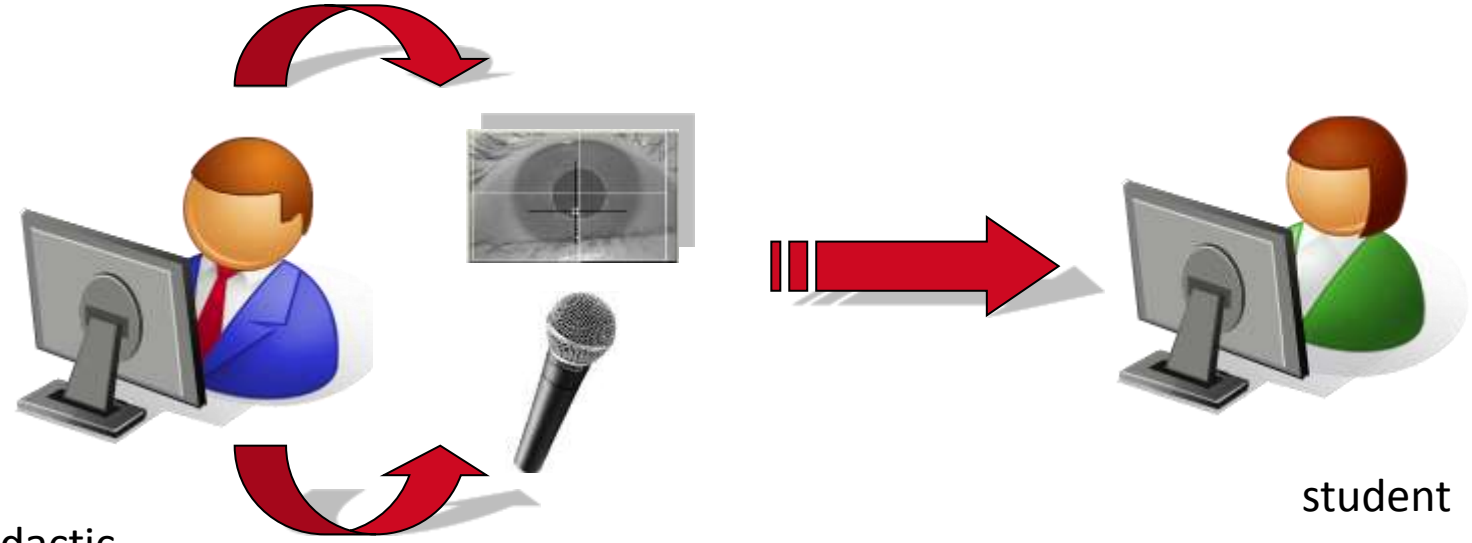
Model **verbalizes** her/his internal states (cf. cognitive apprenticeship (Collins, Brown & Newman, 1989), process-oriented worked-examples (Van Gog, Paas, & Van Merriënboer, 2004))

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

We need to model *perceptual* skills!

Van Gog, Jarodzka, Scheiter, Gerjets, & Paas, 2009. *Computers in Human Behavior*

Novel instructional approach: Eye movement modeling examples



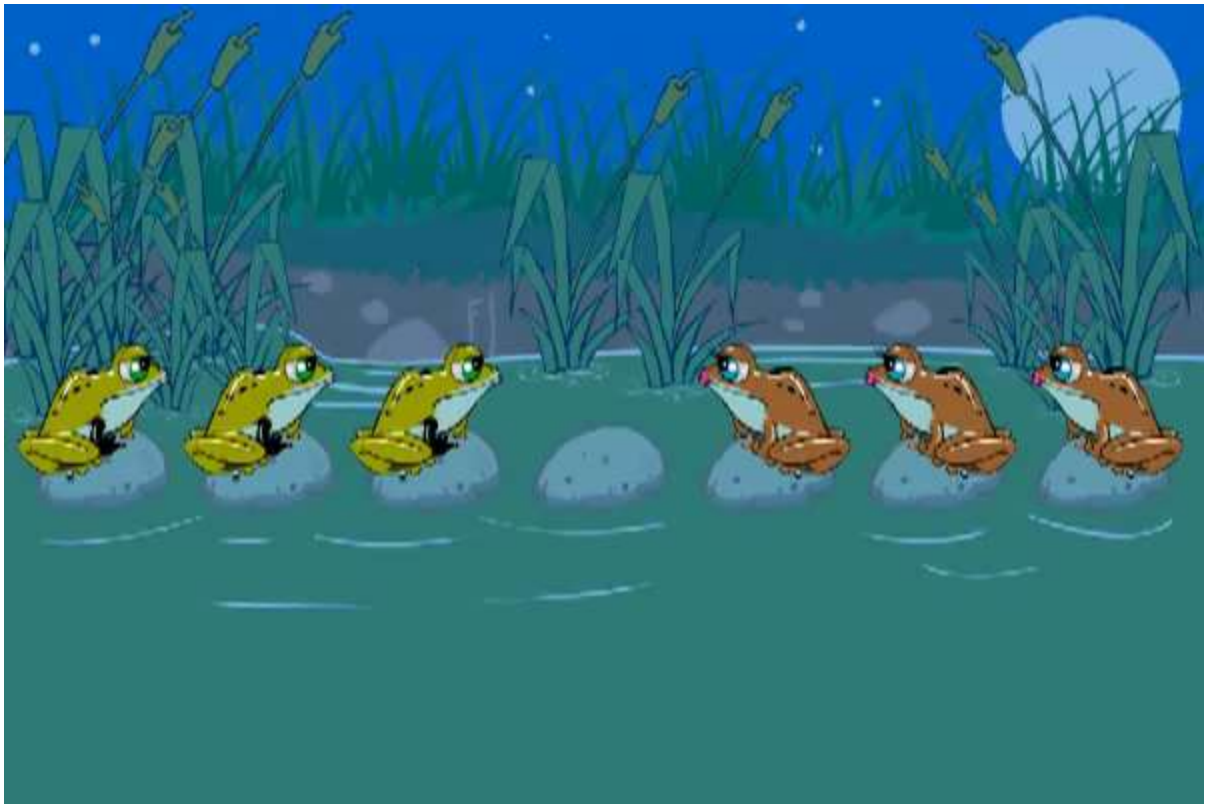
didactic model

student

Moreover: Dorr, Jarodzka, & Barth, 2010; Jarodzka, Scheiter, Gerjets, Van Gog, & Dorr, 2009; Jarodzka, Balslev, Holmqvist, Nyström, Scheiter, Gerjets, & Eika, 2010;

Van Gog, Jarodzka, Scheiter, Gerjets, & Paas, 2009. *Computers in Human Behavior*

First implementation of EMME in a procedural task



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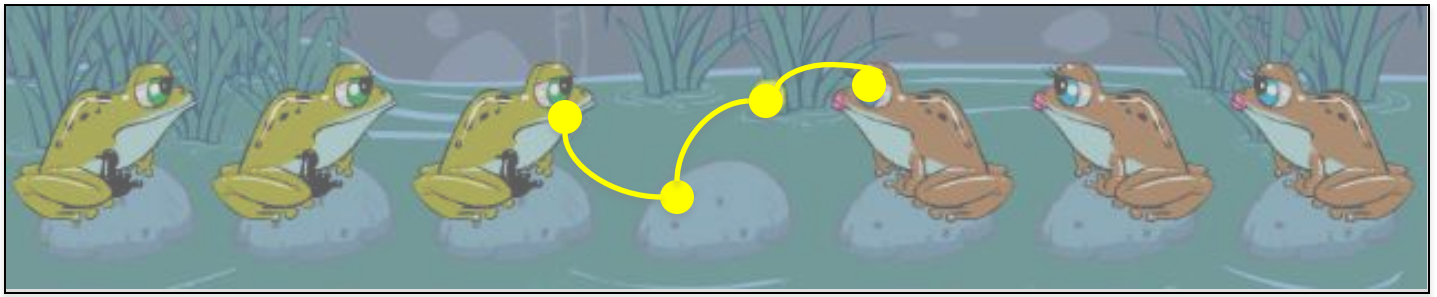
First implementation of EMME in a procedural task



→ 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?

Dorr, Jarodzka, & Barth, 2010. *Eye Tracking Research and Applications: ACM*

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**

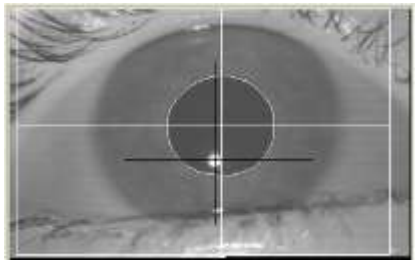
Design

N = 60 medical students in their final year

Eye movement modeling examples during **learning**

Control (none)	Circle display	Spotlight display
		
n = 20	n = 20	n = 20

Research questions



During **learning**:

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

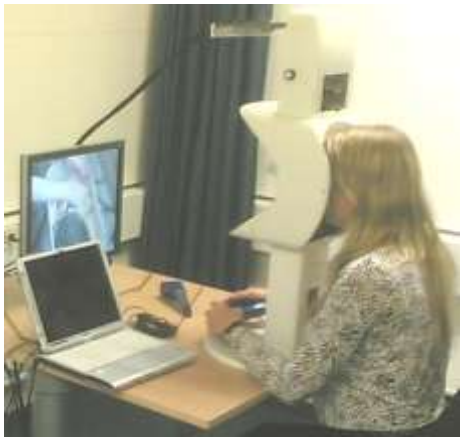
During **testing**:

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

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

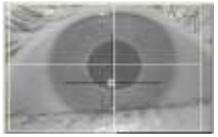
Procedure

SMI High Speed 240 Hz



Learning

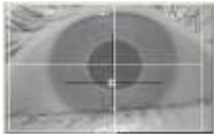
EMME
(no vs. dot vs. foveation)



- Does **EMME guide** the students' attention?

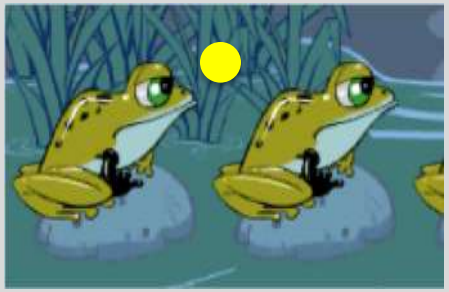
Testing

New videos without guidance



- Does **EMME** lead to a more efficient **visual search**?
- Does **EMME** lead to a better **interpretation** performance?

EMME implemented in different domains



- leapfrog flash game

Van Gog, Jarodzka, Scheiter, Gerjets , & Paas, 2009. *Computers in Human Behavior*

- classifying locomotion patterns of reef fish

Jarodzka, Van Gog, Dorr, Scheiter, & Gerjets, 2009. *Proceedings CogSci*

- diagnosing epileptic seizures in infants

Jarodzka, Balslev, Holmqvist, Nyström, Scheiter, Gerjets, & Eika, 2010. *Proceedings CogSci*

Jarodzka, Van Gog, Dorr, Scheiter, & Gerjets, subm.

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

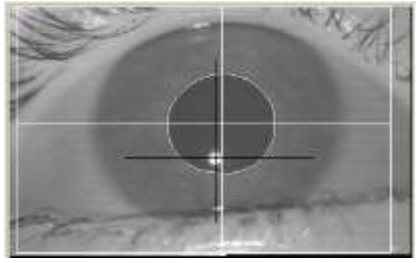
→ Epileptic seizures in pediatric neurology

2. Optimizing the **design** of eye movement display:

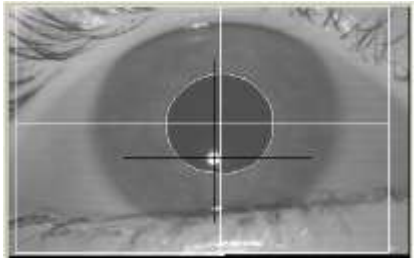
- **Spotlight** more subtle: holistic perception of scene possible
- Dot → **Circle**, as the relevant elements are so small that they would be covered by a dot

Jarodzka, Balslev, Holmqvist, Nyström, Scheiter, Gerjets, & Eika, subm.

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)

	task				
	problem solving	biological classification		medical diagnosis	
perceptual complexity	low	high		very high	
	design				
					
attention guidance	?	↑	↑	✖	↑
visual search	?	✖	↑	✖	↑
interpretation	[↓]	↑	✖	✖	↑

My very last slide...

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!

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