ADAPTIVE LEARNING GAMES USING EYE-TRACKING AND A.I.

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AGENDA

- Motivation, Problem Statement, Adaptivity, Eye Tracking
- Concept, Solution Approach
- Modeling for Games and Eye Tracking
- Evaluation Study
- Conclusion & Outlook

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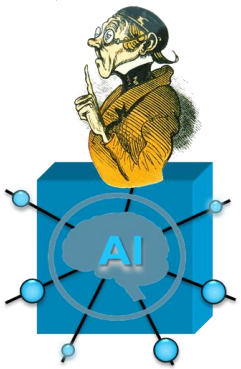
Topic

Adaptive (with A.I.) Serious Games and Eye Tracking

Intelligent
Tutoring Systems (ITS)



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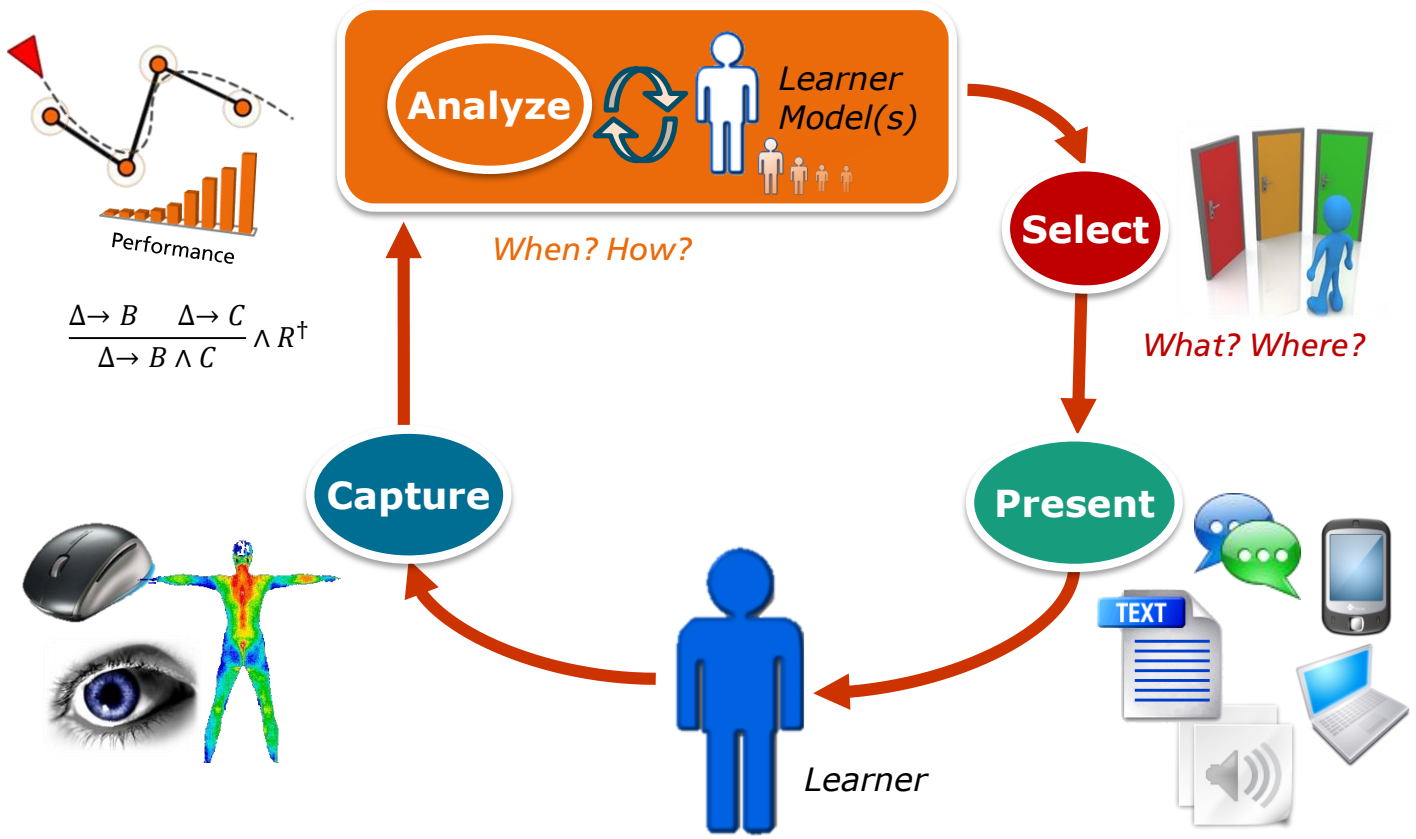
Adaptivity Cycle



Based on Four-Process Adaptive Cycle by V. Shute and D. Zapata-Rivera, "Adaptive educational systems," *Adapt. Technol. Train. …*, no. 1, pp. 1–35, 2012.

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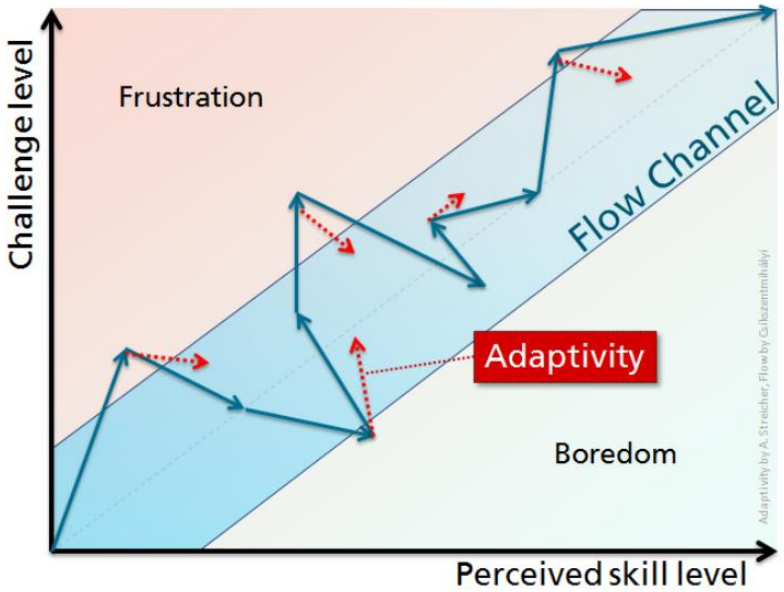
When to adapt?

- When should (must?) an adaptive serious game react?
- React too early – bad! ☹
- React too late – bad! ☹
- Our research:
  - Primary focus on timing (when?)
  - User modeling, e.g. A.I. cognitive modeling → learner/learning state
  - Modeling for flow and immersion [Cruz2017]



Flow: [Csíkszentmihályi1990, Chen2007]

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J. Chen, "Flow in Games (and Everything else)," Communications of the ACM, vol. 50, no. 4, Apr. 2007

M. Csíkszentmihályi, Flow: The Psychology of Optimal Experience. New York: Harper & Row, 1990

C. A. Cruz and J. A. Ramirez Uresti, "Player-centered game AI from a flow perspective: Towards a better understanding of past trends and future directions," Entertainment Computing, vol. 20, May 2017

Our Solution Approach – Applicable, feasable Eye Tracking

Gaze tracking to detect goal-orientedness

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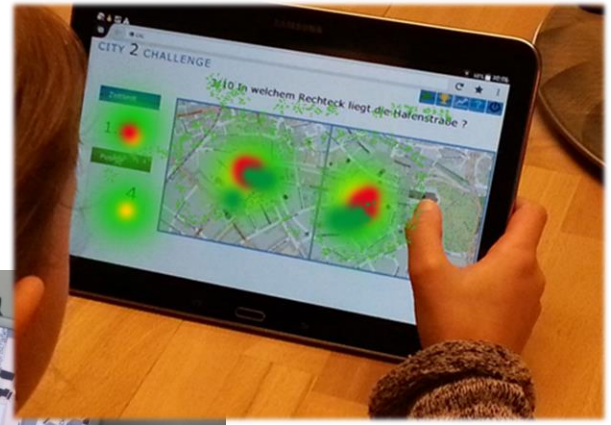
vs.

© Eye Tribe



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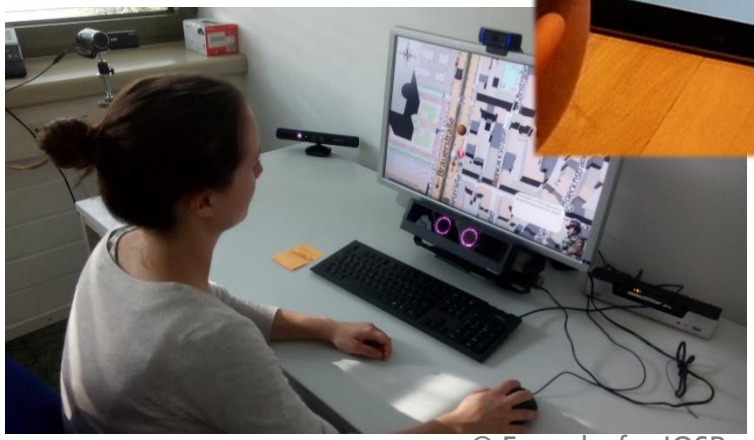

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What to do with Gaze Data? How to interpret?

- There is no semantic information from just X/Y gaze points
- We need a reference model/ground truth

Gaze Plot/Data

How ???

Goal Orientedness
Attention Level
Performance Score

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Adaptation, Personalization, Adaptivity, …

"We define digital adaptive learning tools as education technologies that can respond to a student's interactions in real-time by automatically providing the student with individual support."

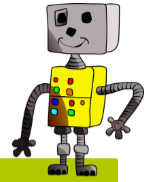
EdSurge, Pearson (2016) Decoding Adaptive. Pearson, London

Personalization

- Manually or automatic
- Individual preferences or needs
- Bsp. avatar design

Adaptability

- Possibility to modify
- Preferences, models
- Offline / online



Adaptivity

- Automatic
- Adaptation to the learner, environment, situation, etc.
- Bsp. dynamic difficulty adjustment

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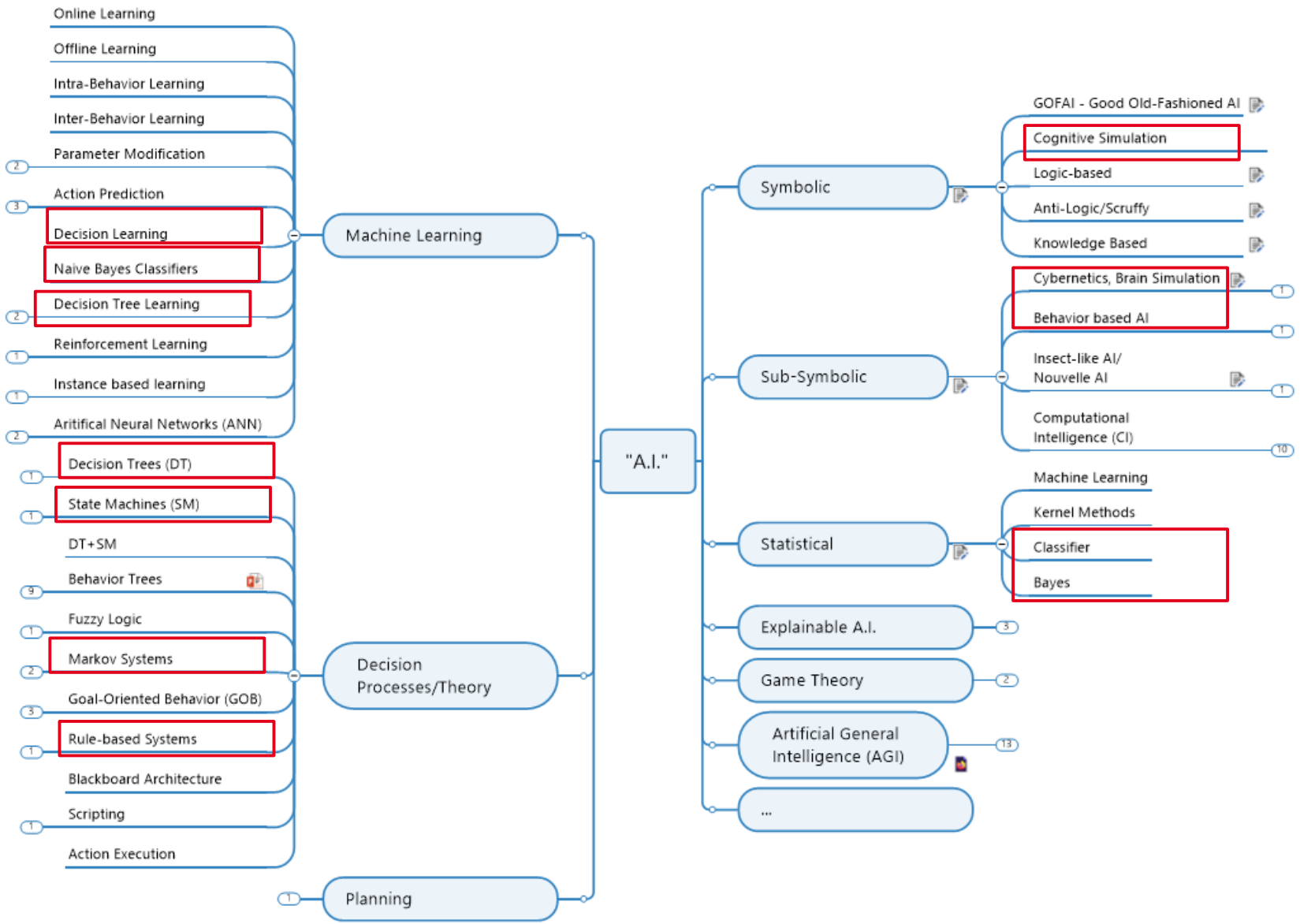
„A.I.“?

- Unsharp term
  (often just marketing?)

Here:

- Methods and technologies to mimic artificial tutoring
- Focus on “explainable A.I.” (XAI)



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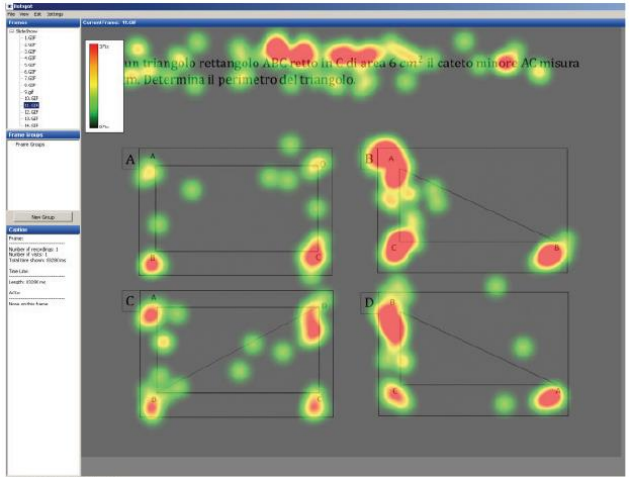
Eye Tracking in a Nutshell



Source [Cantoni 2012]

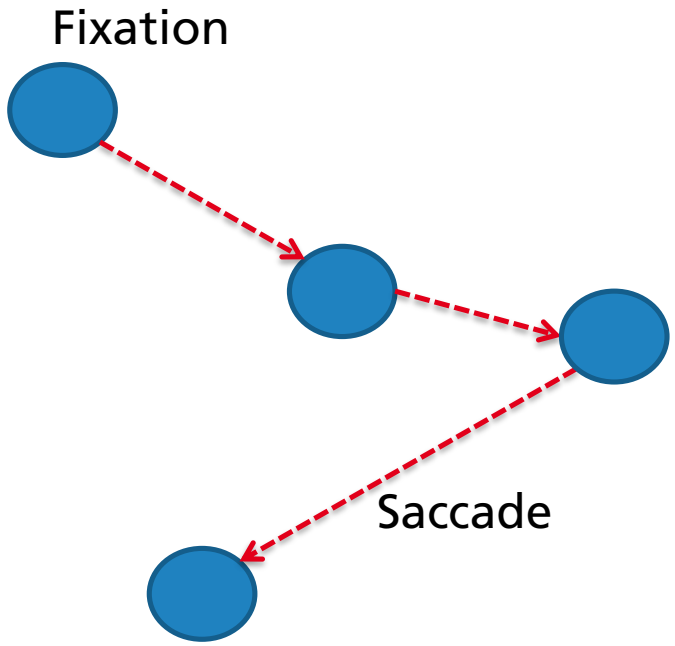
- Measuring of eye movement by infrared light reflected by pupils
- Eye movements allow inferences about the cognitive state [Duchowski 2007]
- Typical terms and metrics:

Fixations
- Eyes stopping and getting fixated
- ~ 90 % of time, lasting 150-600 msec

Saccades
- Short, fast eye movements to reposition the fovea
- Happens between fixations

Blinks
- Closing of the eyes [Galley 2001]
- E.g. indicator of tiredness [Galley01, Barrios04, Calvi08]

...



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N. Galley, "Physiologische Grundlagen, Meßmethoden und Indikatorfunktion der okulomotorischen Aktivität", *Enzyklopädie der Psychologie*, vol. 4, 2001

A. Duchowski, "Eye tracking methodology: Theory and practice", Eye Tracking Methodology: Theory and Practice, pp. 1–328, 2007

Adaptivity – Examples

Content Adaptation:
Modification
of e.g. images

Dynamic Help /
Virtual Agents

[Biegemeier 2016]

Dynamic Difficulty
Adjustment (DDA)

[Lehmann 2015]

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E. Lehmann, "Entwicklung und Akzeptanzanalyse eines kartenbasierten Lernspiels," Bachelor Thesis, Hochschule Karlsruhe - Technik und Wirtschaft; Fraunhofer IOSB, Karlsruhe, 2015.

C. Biegemeier, "Web-basierte Schnittstelle zur Analyse und Adaption von Serious Games," Master Thesis, KIT; Fraunhofer IOSB, Karlsruhe, 2016.

How to enable adaptivity for your game or virtual environment?

xAPI, Activity Streams

„User1 selected console1."

„MaxMustermann started scene power plant 3 minutes ago."

Adaptivity Framework for Serious Games – *„E-Learning A.I."* (ELAI)

Serious Games /

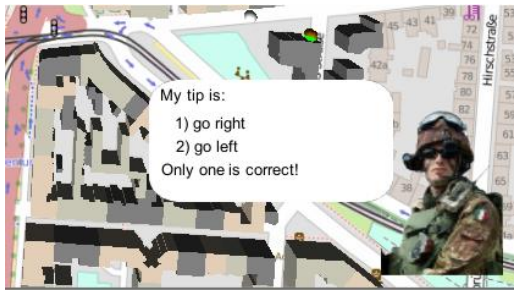
Computer Simulations / …

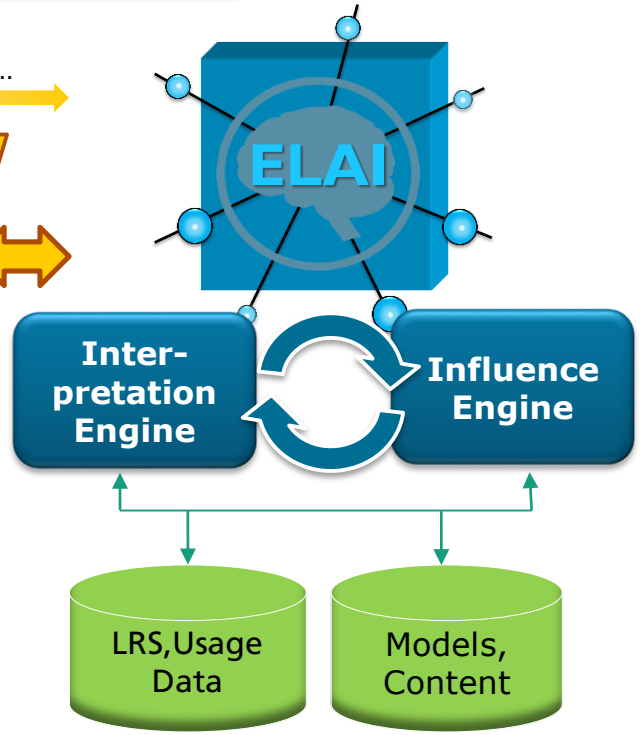
Evidence, Clicks, Statistics, …

ELAI Interface

Comm. Layer (xAPI)

Assistance, States, Objects, …





A. Streicher and W. Roller, "Interoperable Adaptivity and Learning Analytics for Serious Games in Image Interpretation," in *Data Driven Approaches in Digital Education: 12th European Conference on Technology Enhanced Learning, EC-TEL 2017*.

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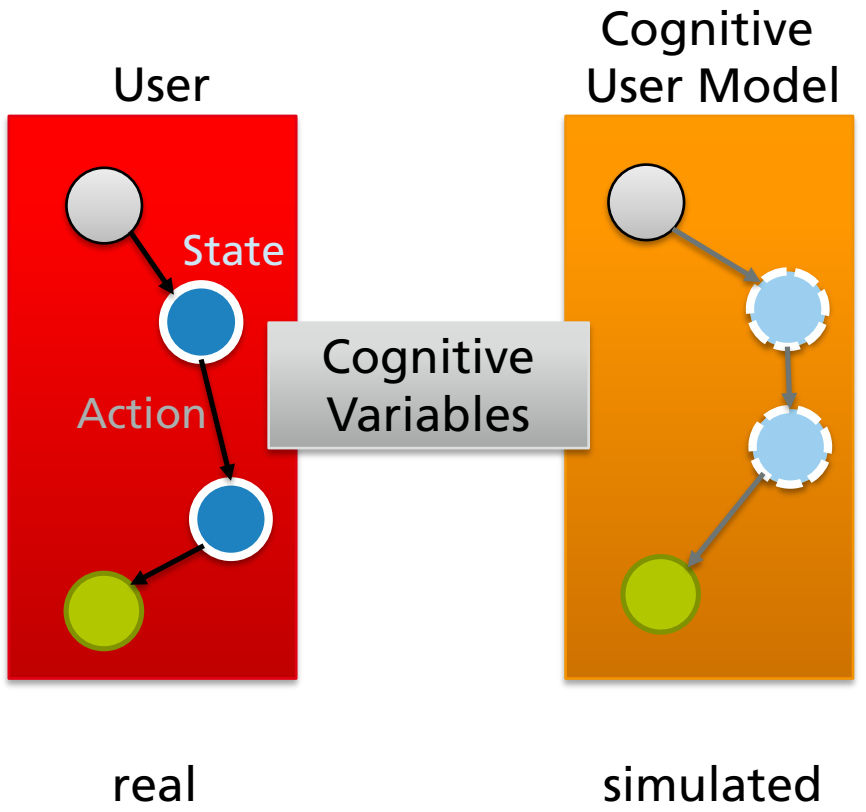
A.I. Modeling

- Adaptivity quality ~ Information about the user
- Models on the application (game) are needed to evaluate user interactions



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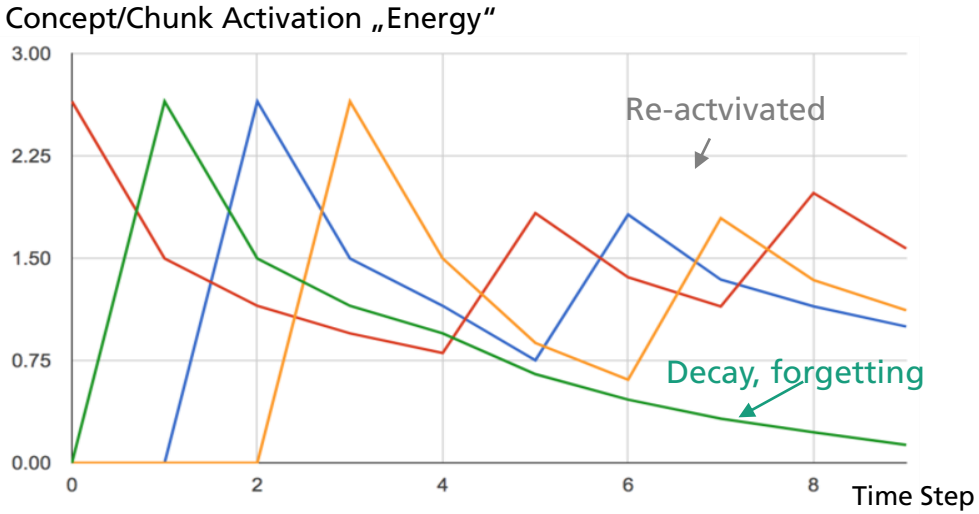
A.I. Modeling – What does the user know/not know?

- Address question “when to adapt…?”

- Cognitive Modeling for user/learner models
  [Busch2018, Aydinbas2019]
  - Forgetting, attention, workload, difficulty, …
  - Generative hierarchical models (Bayesian)
    → estimate states and actions
  - Infer user`s current (latent) state from observed variables

+ “Ideal Path Model” as reference model to evaluate interactions



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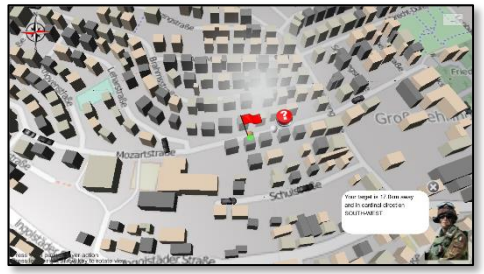
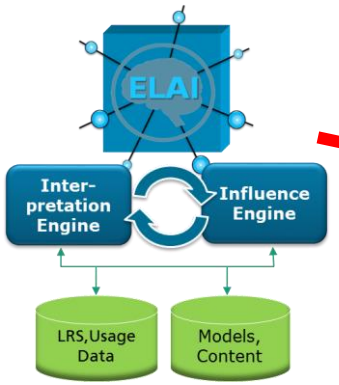
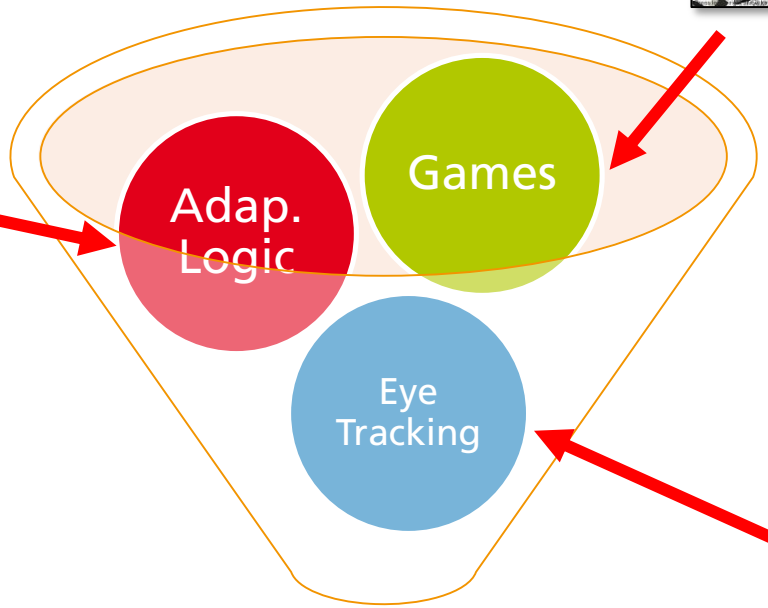
J. Busch, “Einsatz künstlicher Intelligenz in adaptiven Lernsystemen,” Bachelor Thesis, KIT; Fraunhofer IOSB, Karlsruhe, Germany, 2018.

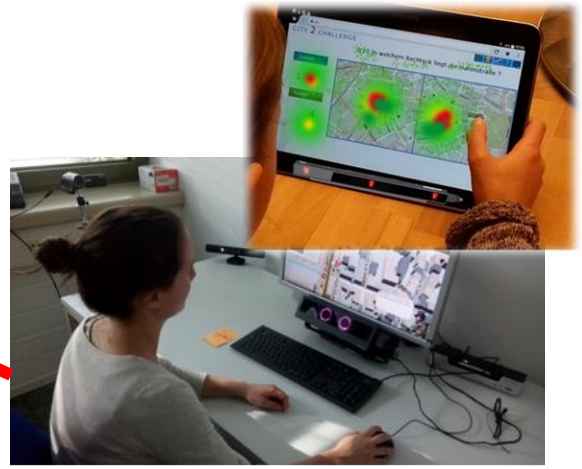
M. Aydinbas, “Realizing Cognitive User Models for Adaptive Serious Games,” Master Thesis, TU Darmstadt; Fraunhofer IOSB, Darmstadt, 2019.

Solution – Adaptivity & Eye-Tracking









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Best Adaptivity for
Serious Games?
How?

Eye-Tracking for additional information

- Problem:

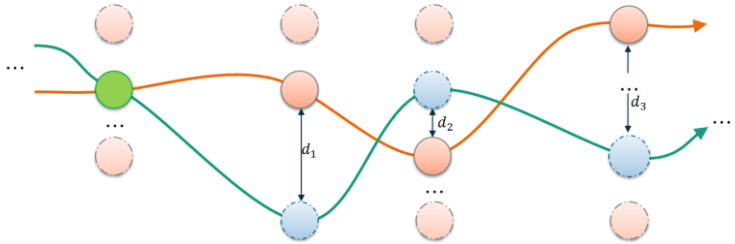
  User interactions (mouse clicks etc.) alone yield incomplete picture

- Solution approach:

  Eye-tracking as additional information source
  [Kiili 2014]

- Challenge:

  How to classify gaze tracks?



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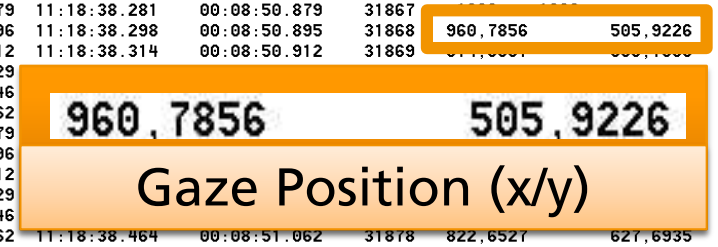

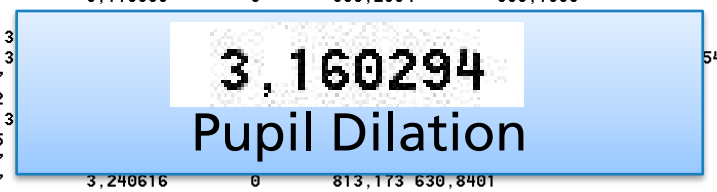

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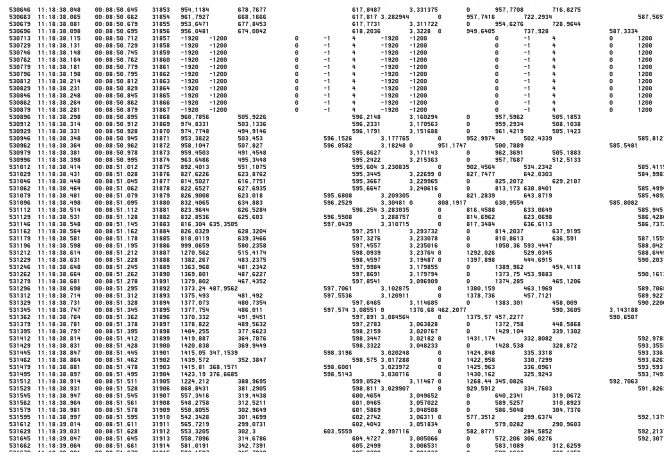
From raw gaze data to information



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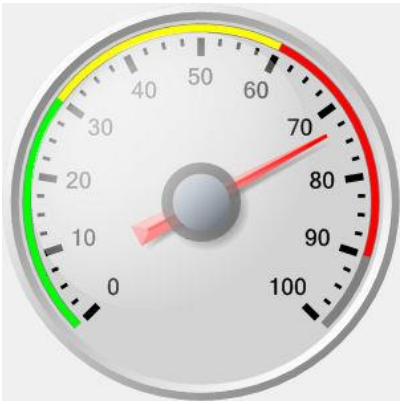

Goal Orientedness
Attention Level
Performance Score

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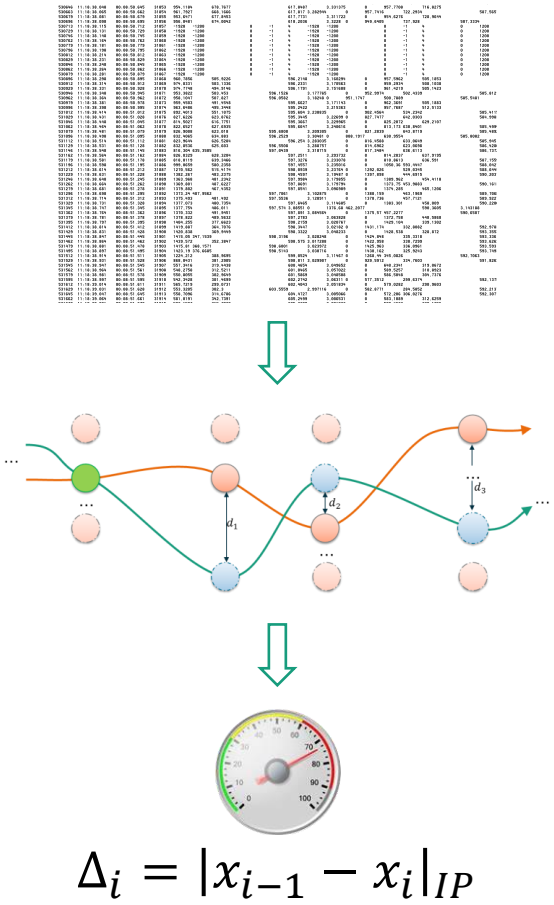
Ideal Path Model (IPM)

- How to relate game context with observed data?
- Idea:
  - Establish a reference model for a user's "Ideal Path" through a learning system/game
  - Goal oriented behavior aligned with an "Ideal Path"
  - Quantify derivations of actual path from ideal path



A. Streicher, S. Leidig, and W. Roller, "Eye-Tracking for User Attention Evaluation in Adaptive Serious Games," in *13th European Conference on Technology Enhanced Learning, EC-TEL 2018*, Leeds, UK, 2018.

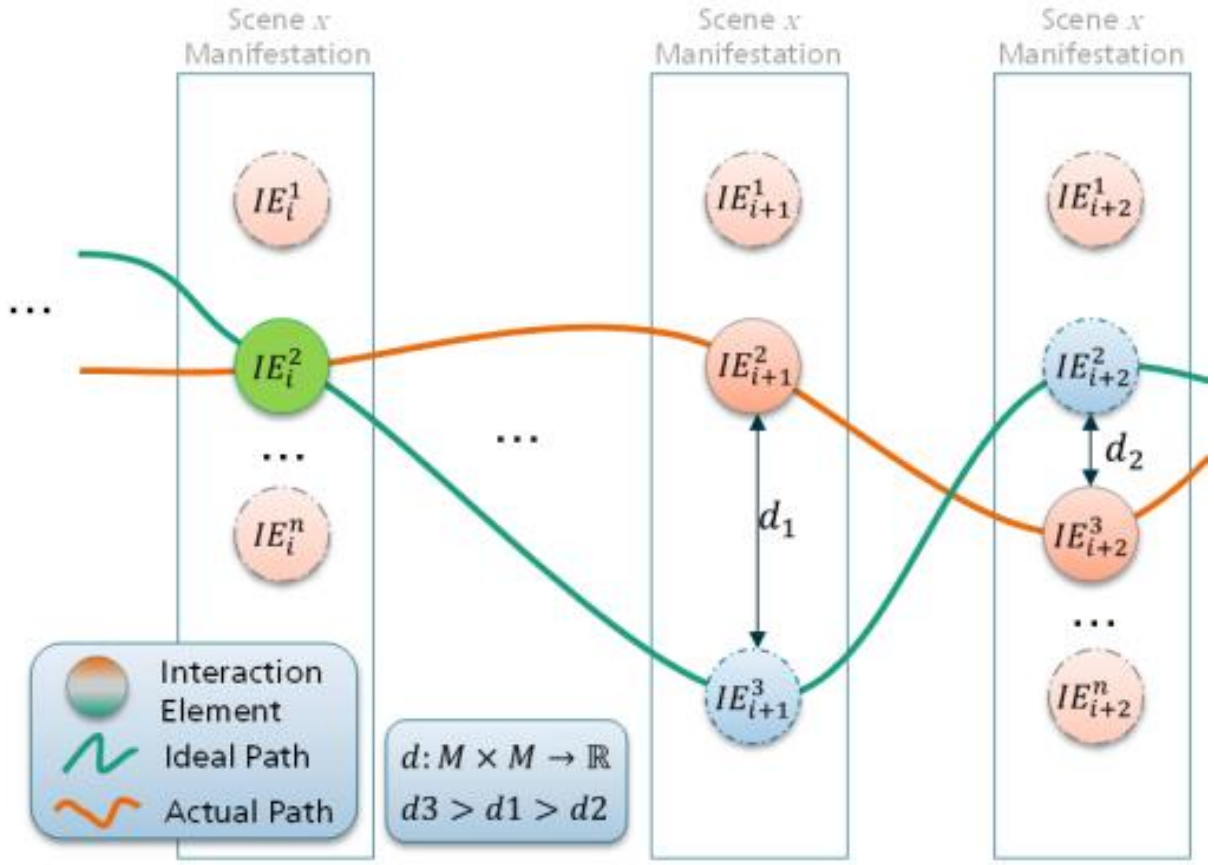
Ideal Path Score

Normalized Score:

+1 ≡ good, progress

0 ≡ neutral, no progress

-1 ≡ bad, regression



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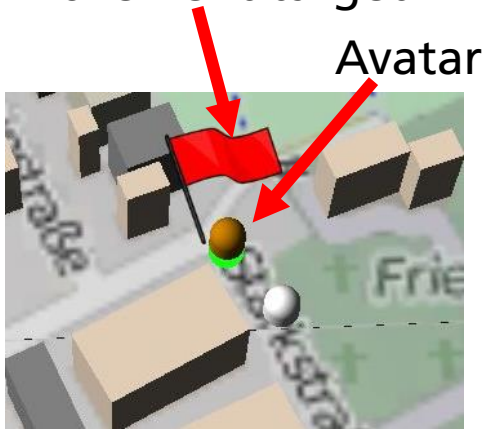
Example: SaFIR (Seek and Find for Image Reconnaissance)



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- Seek & Find game, 2.5D isometric
- Objective: Seek and find tasks, e.g. find locations, specific vehicle types, …
- Learning goals: learn maps/surroundings, differentiate vehicle types

C. Biegemeier, "Web-basierte Schnittstelle zur Analyse und Adaption von Serious Games," Master Thesis, KIT; Fraunhofer IOSB, Karlsruhe, 2016.

Example: SaFIRa (SaFIR adaptive)

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Adaptive
Virtual Agent hints:

Your target is 17.0km away and in cardinal direction SOUTH-WEST

C. Biegemeier, "Web-basierte Schnittstelle zur Analyse und Adaption von Serious Games," Master Thesis, KIT; Fraunhofer IOSB, Karlsruhe, 2016.

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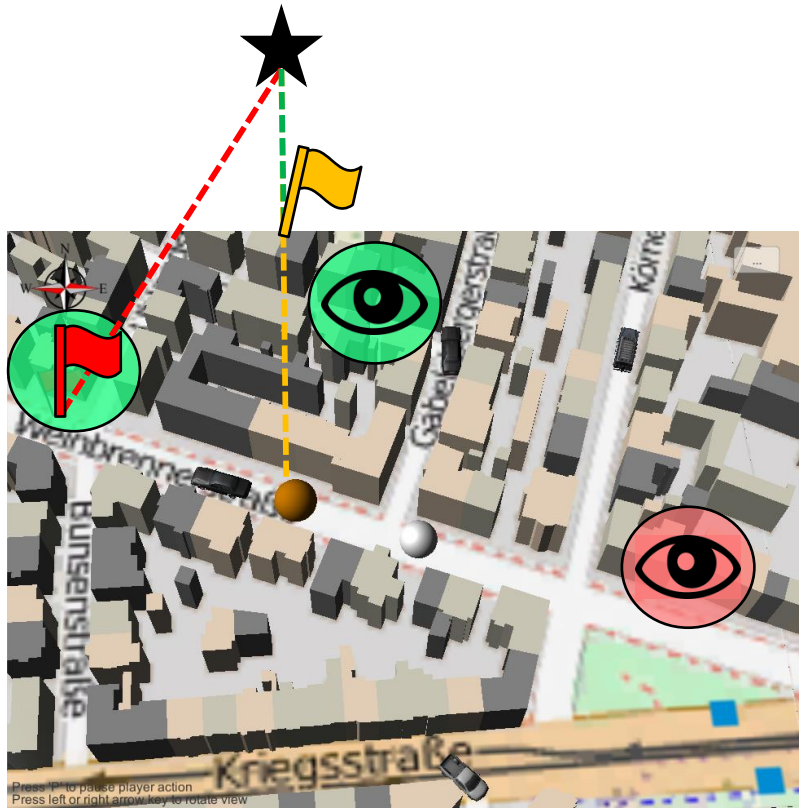
SaFIRa: Defining an Ideal Path Score



$$Score = \alpha S_{Move} + (1 - \alpha) S_{Gaze}$$

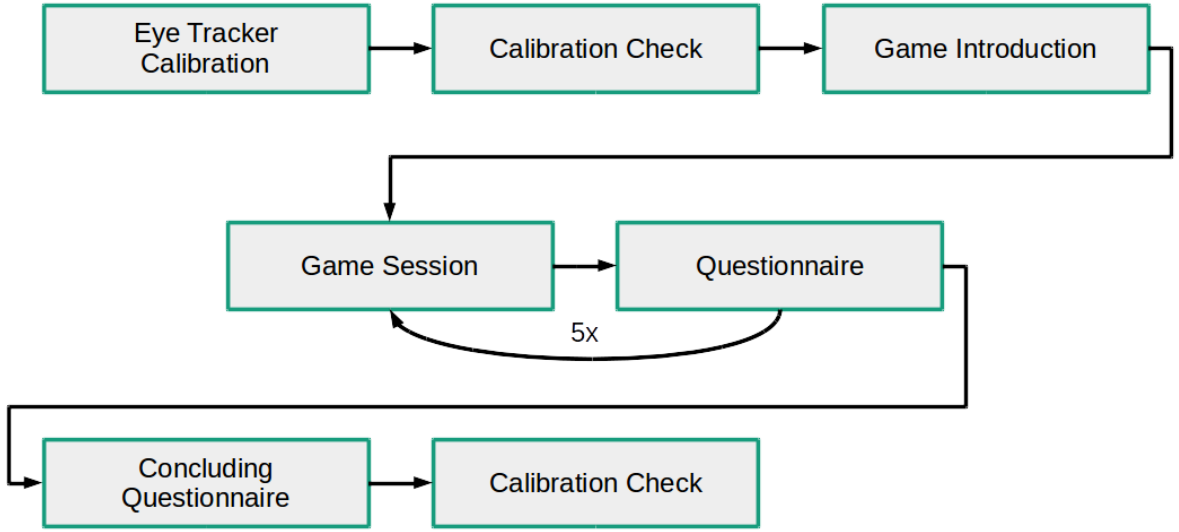
$$S_{Move} = \frac{TargetDistanceChange_{actual\ move}}{TargetDistanceChange_{ideal\ move}}$$

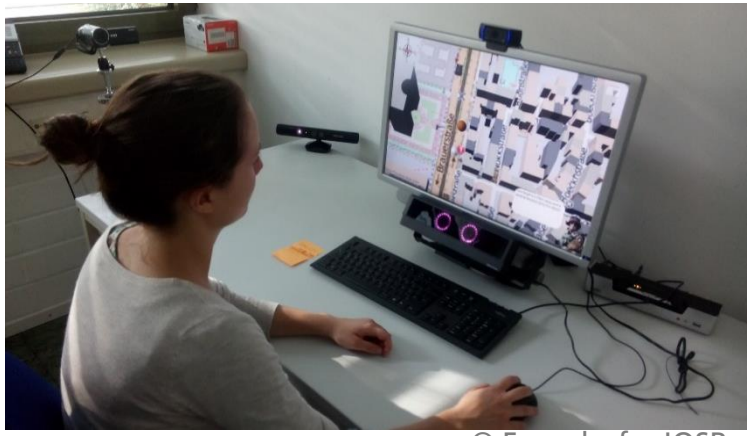
$$S_{Gaze} = \sum_{f \in Fixations} fixationValue(f) \frac{duration(f)}{duration_{step}}$$

S. Leidig, "Analysis of User Attention for Adaptive Serious Games - Design and Implementation of an Evaluation Framework," Master Thesis, KIT; Fraunhofer IOSB, 2016.

Study

- Hypothesis
  - *Ideal Path Score (IPS) correlates with self-reported attention & goal-orientedness*
  - *Eye tracking features improve correlation*
  - *IPS improves adaptivity decisions*
- Control group
  - Without Eye-Tracking Adaptivity
  - With Eye-Tracking Adaptivity (IPS)
- Recorded 86 game sessions, n=20





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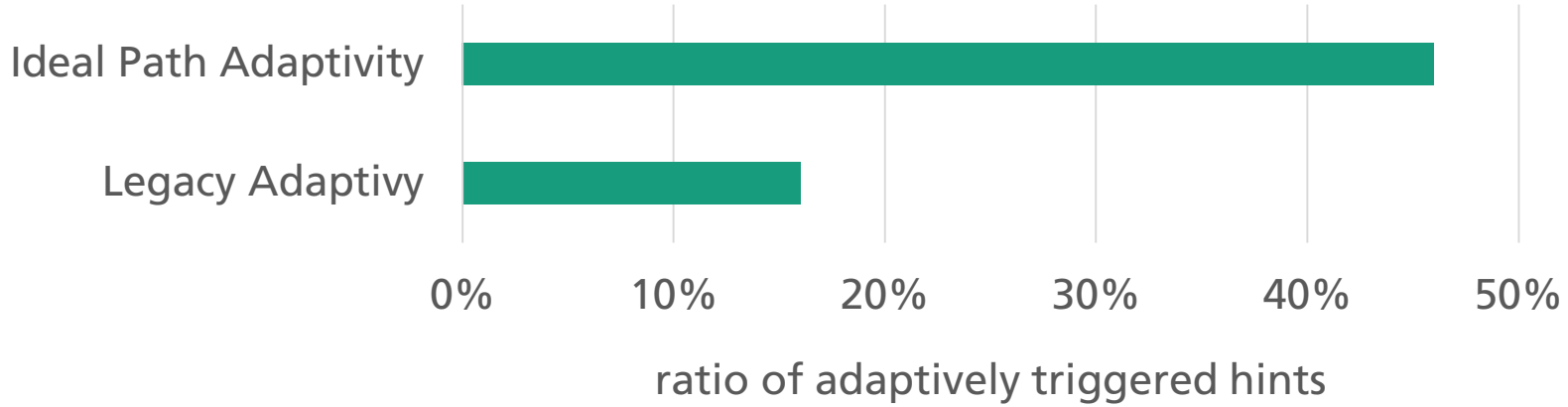
Streicher, Alexander, Sebastian Leidig, and Wolfgang Roller. "Eye-Tracking for User Attention Evaluation in Adaptive Serious Games." In 13th European Conference on Technology Enhanced Learning, EC-TEL 2018, 583–86. Leeds, UK: Springer, 2018.

Study Results

- Ideal Path Score improves adaptive display of help [Streicher2018, Leidig2016]



- Limitations, challenges:
  - Few „distracted“ participants during experiment → “Attention“ difficult to measure
  - Evaluation setting in parts too complex, too high DoF → simplification needed

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Leidig, Sebastian. “Analysis of User Attention for Adaptive Serious Games - Design and Implementation of an Evaluation Framework.” Master Thesis, KIT; Fraunhofer IOSB, 2016.

Streicher, Alexander, Sebastian Leidig, and Wolfgang Roller. “Eye-Tracking for User Attention Evaluation in Adaptive Serious Games.” In 13th European Conference on Technology Enhanced Learning, EC-TEL 2018, 583–86. Leeds, UK: Springer, 2018.

Conclusion & Outlook

- Eye tracking to augment adaptivity decisions for serious games (“when to adapt”)
- Focus on feasibility by using COTS hardware (only regions, not pixel precise)
- Use e-learning standards, e.g. xAPI, and interoperability architecture for adaptivity
- Generic *Ideal Path Score* to measure progress (reference model and metric)

Outlook

- Transfer to other game genres and application domains, e.g., serious game for cyber security
- Combination of modeling approaches (cognitive modeling + ideal path model)
- Further evaluation studies

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Thanks.
Questions? Comments?

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