# 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



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.

# When to adapt?

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







© Fraunhofer IOSB 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 Al 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.

# 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





Goal Orientedness Attention Level Performance Score



# 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





"A.I."?

Unsharp term
 (often just marketing?)

Here:

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







# Eye Tracking in a Nutshell

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

. . .

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Fixations	<ul> <li>Eyes stopping and getting fixated</li> <li>~ 90 % of time, lasting 150-600 msec</li> </ul>
Saccades	<ul> <li>Short, fast eye movements to reposition the fovea</li> <li>Happens between fixations</li> </ul>
Blinks	<ul> <li>Closing of the eyes [Galley 2001]</li> <li>E.g. indicator of tiredness [Galley01, Barrios04, Calvi08]</li> </ul>







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]

© Fraunhofer IOSB 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?





# A.I. Modeling

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







# 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



Seite 14 © Fraunhofer IOSB J. Busch, "Einsatz künstlicher Intelligenz in adaptiven Lernsystemen," Bachelor Thesis, KIT; Fraunhofer IOSB, Karlsruhe, Germany, 2018.

14

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







# **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:

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How to classify gaze tracks?







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530812	11:18:38.214	00:08:50.812	31863	-1920 -1200	
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530846	11:18:38.248	00:08:50.845	31865	-1920 -1200	
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# From raw gaze data to information







Goal Orientedness Attention Level Performance Score



# 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**







20

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.

# **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



### Example: SaFIR<u>a</u> (SaFIR <u>adaptive</u>)



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IOSB, Karlsruhe, 2016.

C. Biegemeier, "Web-basierte Schnittstelle zur Analyse und

Adaption von Serious Games," Master Thesis, KIT; Fraunhofer

Adaptive Virtual Agent hints:

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



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### SaFIRa: Defining an Ideal Path Score



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



S. Leidig, "Analysis of User Attention for Adaptive Serious

Games - Design and Implementation of an Evaluation

Framework," Master Thesis, KIT; Fraunhofer IOSB, 2016.

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



# Study

#### Hypothesis

- Ideal Path Score (IPS) correlates with selfreported 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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Seite 24

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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.

### **Study Results**

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



- Limitations, challenges:
  - Few "distracted" participants during experiment  $\rightarrow$  "Attention" difficult to measure
  - Evaluation setting in parts too complex, too high DoF  $\rightarrow$  simplification needed

© Fraunhofer IOSB Carlous 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)

#### <u>Outlook</u>

- 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. Questíons? Comments?

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emtec www.emtec.de



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