

# Analyzing interactions and processes in an adaptive and evidence-based consumer health information system

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BEDEK Michael<sup>1</sup>  
SCHRAMM Niklas<sup>1</sup>  
LENGAUER Stefan<sup>2</sup>  
KRENN Cornelia<sup>3</sup>  
ALBERT Dietrich<sup>1</sup>  
SCHRECK Tobias<sup>2</sup>

<sup>1</sup>University of Graz, <sup>2</sup>Graz University of Technology, <sup>3</sup>Medical University of Graz



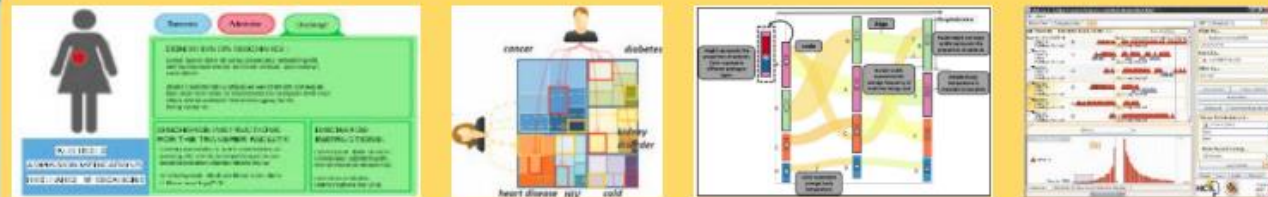
# A<sup>+</sup>CHIS Project

<https://apchis.cg.v.tugraz.at/>

Domain: T2DM



## Evidence-based Consumer Health Information (Area 2)



## A<sup>+</sup>CHIS: Novel Concepts and Testbed Systems for Visual Adaptive Consumer Health Information



## Knowledge Visualization for Adaptive Health Information (Area 1)



## Cognitive Psychology of Adaptive Health Information Systems (Area 3)

The screenshot illustrates the A+CHIS platform interface, which is designed for health information exploration. Key components include:

- Table of Contents:** A list of topics, with the first topic being "1 „Ich habe Diabetes“ - was bedeutet das?".
- Topicbar:** A horizontal bar with five colored tabs labeled Topic 1 through Topic 5.
- Word Cloud:** A cloud of words related to diabetes, with "Diabetes" and "Insulin" being prominent. A box highlights the word "Krankheit".
- History Word Cloud:** A smaller word cloud showing terms like "Symptom", "Blut", "Zuckerkrankheit", and "Diabetes".
- Image Slider:** A series of small images showing people and medical equipment.
- History Image Slider:** A smaller version of the image slider.
- Tilebar:** A grid-based visualization titled "Distribution of Krankheit" showing the relationship between "symptom" and "Krankheit".
- Snippets:** A list of text snippets related to diabetes, such as "1. Warum ist Diabetes überhaupt gefährlich?".
- Full Text:** A detailed view of a snippet, showing the full text of a section titled "1.3. „Selbst schuld?“ - wie Diabetes entsteht".

Interactions are indicated by dashed blue arrows: a "(hover)" arrow points from the "Krankheit" word in the Word Cloud to the "Krankheit" tile in the Tilebar, and a "(click)" arrow points from the "Krankheit" tile to the "Full Text" view.

Lengauer, S., Shao, L., Miri, H., Bedek, M.A., Kupfer, C., Zangl, M., Kubicek, B., Dienstbier, B.C., Jeitler, K., Krenn, C., Semlitsch, T., Zipp, C., Albert, D., Siebenhofer-Krotzsch, A. & Schreck, T. (submitted). A Visual Approach for Health Information Exploration.

Content: Baumgart, J., Viegner, U. & Pohl, C. (2021). Den Diabetes im Griff: Ein Handbuch für Patientinnen und Patienten mit Diabetes Mellitus typ 2. AOK-Bundesverband, Berlin. URL: <https://www.aok.de/pk/magazin/cms/fileadmin/pk/pdf/patientenhandbuch-diabetes.pdf>

# Procedure of a small study (comparing A<sup>+</sup>CHIS with Acrobat Reader)

- 5 Parts:
  - I. Intro & Instruction
  - II. Cognitive Walkthrough 1 (A<sup>+</sup>CHIS / Acrobat Reader)
  - III. Cognitive Walkthrough 2 (Acrobat Reader / A<sup>+</sup>CHIS)
  - IV. Quantitative Comparisons
  - V. Qualitative Interview
- Original Idea: CWTs as mean to allow for Parts IV and V,
- Think Aloud, Audio & Screenrecordings
- $n = 12$  (8 male); 26-62 yrs. ( $M = 40$  yrs.,  $SD = 14$  yrs.)
- Self-assessment on a 5-point Likert Scale:
  - Pre-knowledge on T2DM ( $M = 1.00$ ,  $SD = 1.21$ )
  - Computer and software skills ( $M = 2.25$ ,  $SD = .97$ )
  - Experiences with Visualizations ( $M = 2.58$ ,  $SD = 1.24$ )

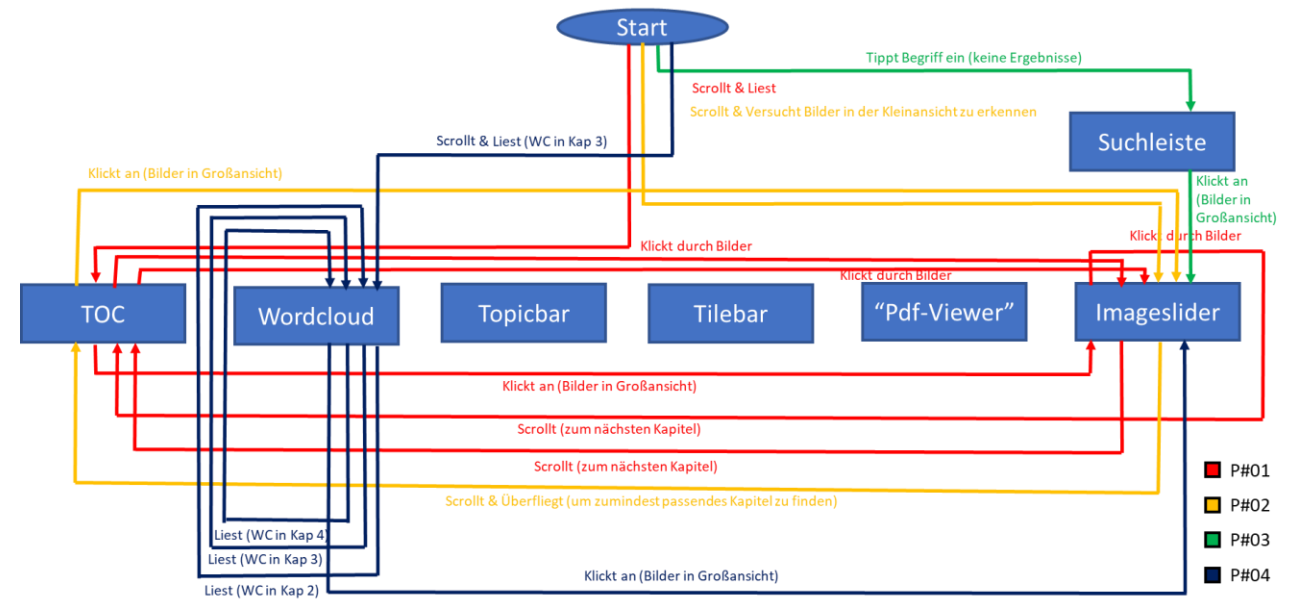
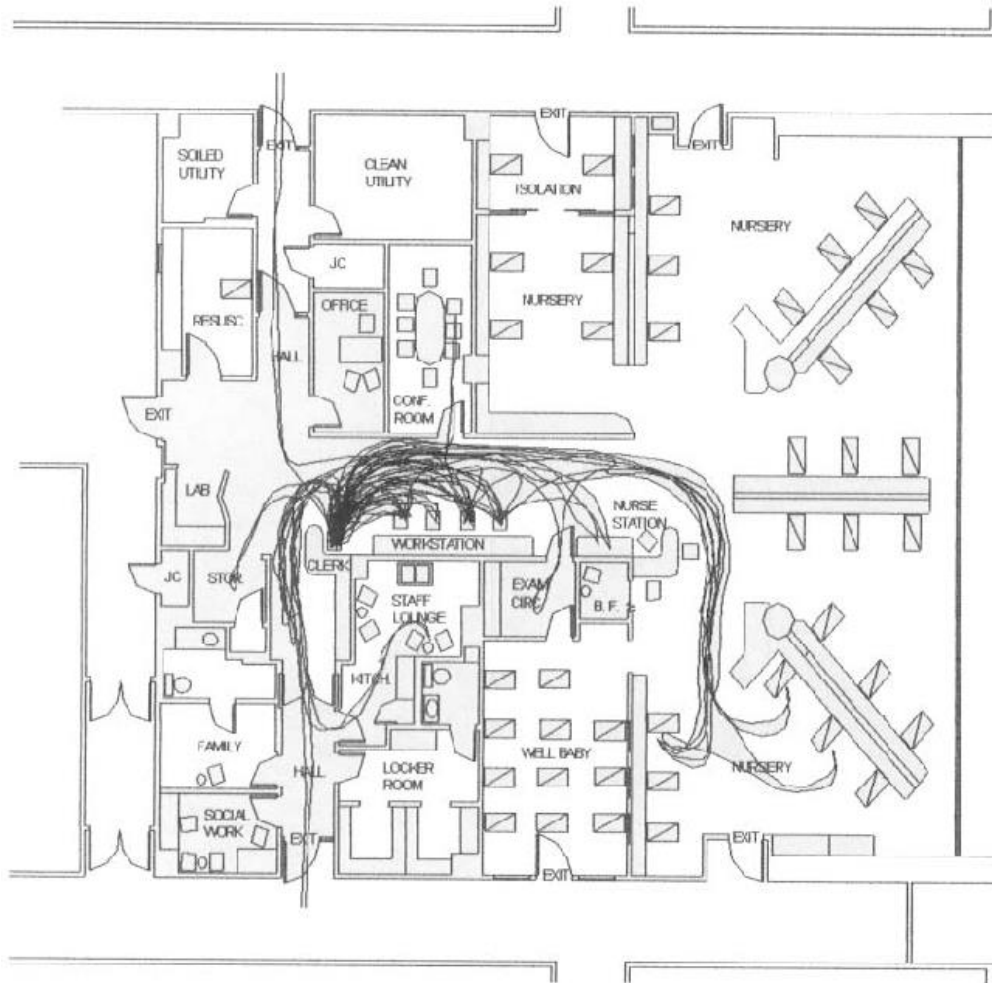


# Tasks

## The CWT Tasks.

| Task | Parallel Version 1   | Parallel Version 2  |
|------|--|---|
| WC1  | Which contents/subject areas do you think are included in chapter 5?   | Which contents/subject areas do you think are included in chapter 3?  |
| WC2  | What is the waist size that creates a greatly increased risk for men?  | What daily amounts of beer/alcohol are just acceptable for men?   |
| WC3  | How does type I diabetes mellitus develop?   | How does type II diabetes mellitus develop?   |
| WC4  | What contents/terms have you searched for so far?  | What contents/terms have you searched for so far?   |
| TiB1 | How often does the term 'smoking' appear in chapter 1?   | How often does the term 'stress' appear in chapter 1?   |
| TiB2 | Is it worth reading beyond chapter 2 if you want to learn exclusively about 'diastole'?                        | Is it worth reading beyond chapter 4 if you want to learn exclusively about 'medication'?                       |
| TiB3 | Does chapter 2 give a better insight into the topic of 'care' than chapter 6?                                  | Does chapter 6 give a better insight into the topic of '(diabetic) foot' or 'foot syndrome' than chapter 3?     |
| TiB4 | In which chapter would you most likely start if you wanted to find out more about 'blood pressure'?            | In which chapter would you most likely start if you wanted to find out more about 'insulin'?                    |
| IS1  | According to an illustration in chapter 5, is a sugar value of 100 mg/dl alarming or safe?                     | Which 3 stages of diabetes therapy are shown graphically in chapter 4?  |
| IS2  | Which picture in chapter 6 do you think conveys the most relevant information about type II diabetes mellitus? | Which picture in chapter 6 do you think conveys the least relevant information about type II diabetes mellitus? |
| IS3  | Search for a graphic on the topic of 'sugar metabolism'.   | Search for a graphic on the topic of 'nutrition pyramid'.   |

# „Source of Inspiration“: Behavioral Mapping



## For what?

- Metrics to elaborate suggestions for improvement?
- Comparison between tasks / participants?
- ‚Central‘ tools / processes for a range of tasks?
- Are there (repeated) loops and cycles that could be avoided?
- ...

## Range of Metrics from Behavioral Mapping:

- (physical) Locations (= Tools)
- Movements (= Edges)
- Activities / Behaviours (= Processes)
- Activities per Location (= Processes per Tool)
- Time per activity
- Common activities per group of people / per location
- ...

*however, other methods?*

# Raw Data

|    | G                | H            | I               | J               | K               | L           |
|----|------------------|--------------|-----------------|-----------------|-----------------|-------------|
| 1  | P_01_WC_2_Vers.2 | Kantennummer | Tool_a          | Prozess         | Tool_b          | Zeit (Sek.) |
| 2  | P_01_WC_2_Vers.2 | 1            | WC_Kap.3        | Hoovern         | WC_Kap.3        | 2           |
| 3  | P_01_WC_2_Vers.2 | 2            | WC_Kap.3        | Anklicken       | PDF_Kap.3       | 1           |
| 4  | P_01_WC_2_Vers.2 | 3            | PDF_Kap.3       | Überfliegen     | PDF_Kap.3       | 8           |
| 5  | P_01_WC_2_Vers.2 | 4            | PDF_Kap.3       | Scrollen        | PDF_Kap.3       | 1           |
| 6  | P_01_WC_2_Vers.2 | 5            | PDF_Kap.3       | Überfliegen     | PDF_Kap.3       | 4           |
| 7  | P_01_WC_2_Vers.2 | 6            | PDF_Kap.3       | Scrollen        | PDF_Kap.3       | 2           |
| 8  | P_01_WC_2_Vers.2 | 7            | PDF_Kap.3       | Überfliegen     | PDF_Kap.3       | 5           |
| 9  | P_01_WC_2_Vers.2 | 8            | PDF_Kap.3       | Kontext erhöhen | PDF_Kap.3       | 2           |
| 10 | P_01_WC_2_Vers.2 | 9            | PDF_Kap.3       | Lesen           | PDF_Kap.3       | 3           |
| 11 | P_01_WC_2_Vers.2 | 10           | PDF_Kap.3       | Scrollen        | PDF_Kap.5       | 1           |
| 12 | P_01_WC_2_Vers.2 | 11           | PDF_Kap.5       | Überfliegen     | PDF_Kap.5       | 11          |
| 13 | P_01_WC_2_Vers.2 | 12           | PDF_Kap.5       | Wegklicken      | Startbildschirm | 1           |
| 14 | P_01_WC_2_Vers.2 | 13           | Startbildschirm | Fixierung       | IS_Kap.3_klein  | 2           |
| 15 | P_01_WC_2_Vers.2 | 14           | IS_Kap.3_klein  | Anklicken       | IS_Kap.3_groß   | 1           |
| 16 | P_01_WC_2_Vers.2 | 15           | IS_Kap.3_groß   | Kommentieren    | IS_Kap.3_groß   | 10          |
| 17 | P_01_WC_2_Vers.2 | 16           | IS_Kap.3_groß   | Sliden          | IS_Kap.3_groß   | 1           |
| 18 | P_01_WC_2_Vers.2 | 17           | IS_Kap.3_groß   | Betrachten      | IS_Kap.3_groß   | 2           |
| 19 | P_01_WC_2_Vers.2 | 18           | IS_Kap.3_groß   | Sliden          | IS_Kap.3_groß   | 1           |
| 20 | P_01_WC_2_Vers.2 | 19           | IS_Kap.3_groß   | Betrachten      | IS_Kap.3_groß   | 3           |
| 21 | P_01_WC_2_Vers.2 | 20           | IS_Kap.3_groß   | Wegklicken      | WC_Kap.3        | 1           |
| 22 | P_01_WC_2_Vers.2 | 21           | WC_Kap.3        | Überfliegen     | WC_Kap.3        | 9           |
| 23 | P_01_WC_2_Vers.2 | 22           | WC_Kap.3        | Anklicken       | PDF_Kap.3       | 1           |
| 24 | P_01_WC_2_Vers.2 | 23           | PDF_Kap.3       | Überfliegen     | PDF_Kap.3       | 4           |

1870 Set of triples:

$\{(tool_1, process_1, tool_2), (tool_2, process_2, tool_3), \dots, (tool_{n-1}, process_n, tool_n)\}$

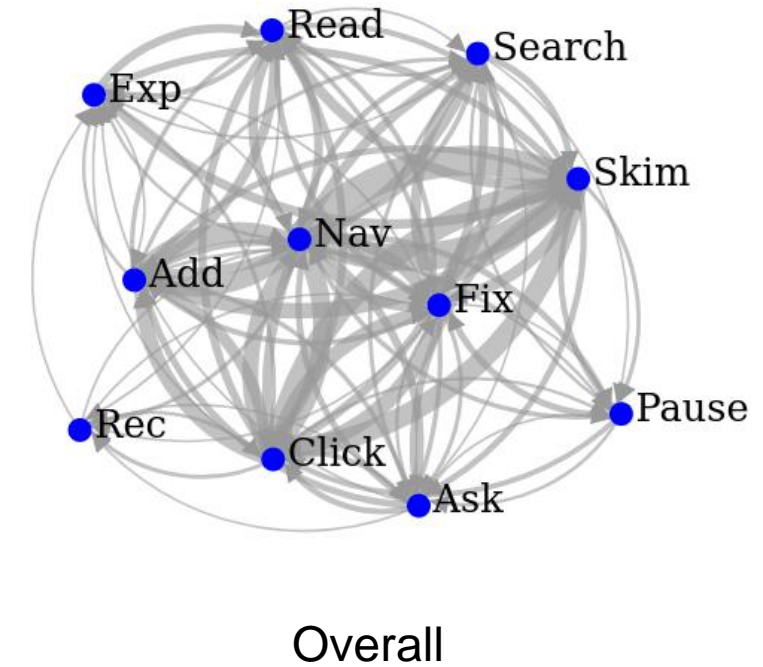
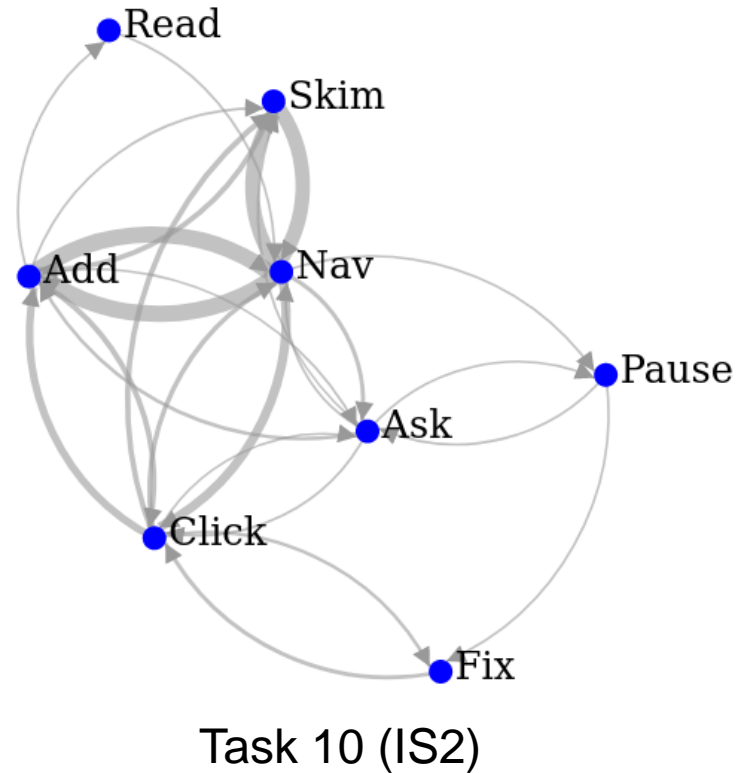
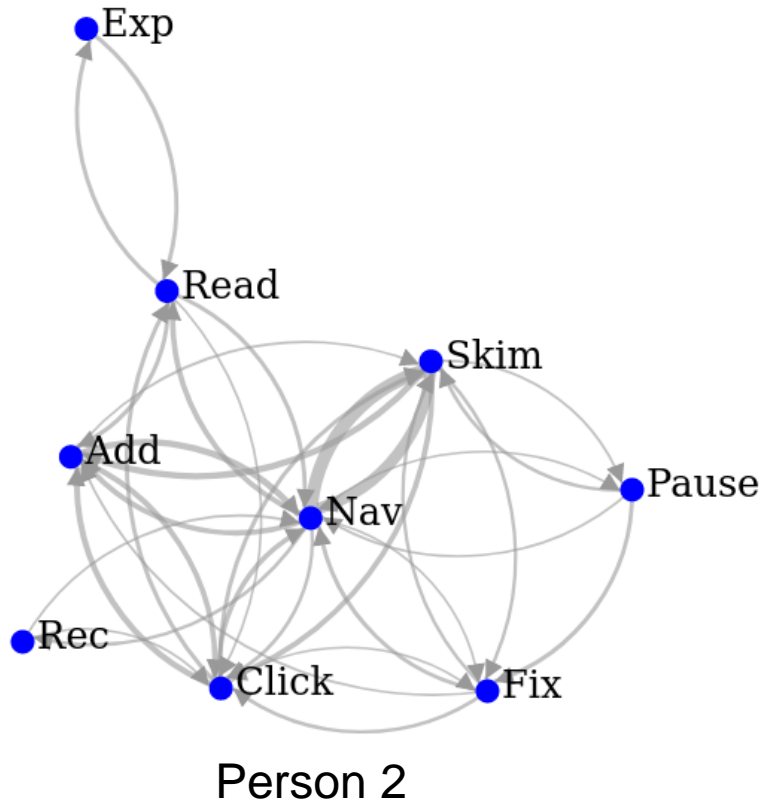
Initially:

28 processes and 86 tools, have been clustered:

- Fixating (Fix)
- Recall from Memory (Rec)
- Hovert / Scanning (Skim)
- Commenting / Interpreting (Add)
- Click
- Expanding (Exp)
- Read
- Ask
- Pause
- Scrolling / Sliding (Nav)
- Search



# Example: Connectivity Graph



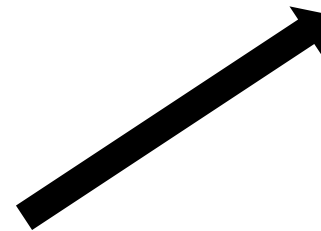
Input: Adjacency Matrix; however, no 'loops' (e.g. Click → Click)

# Lag sequential analysis (LSA)

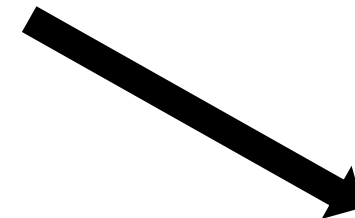
Adjacency Matrix

|        | Fix | Nav | Read | Ask | Add | Skim | Click | Exp | Pause | Rec | Search |
|--------|-----|-----|------|-----|-----|------|-------|-----|-------|-----|--------|
| Fix    | 9   | 20  | 7    | 3   | 5   | 28   | 46    | 0   | 1     | 1   | 19     |
| Nav    | 24  | 158 | 17   | 12  | 64  | 155  | 62    | 2   | 7     | 3   | 6      |
| Read   | 5   | 13  | 0    | 4   | 18  | 6    | 11    | 5   | 0     | 1   | 1      |
| Ask    | 2   | 7   | 0    | 0   | 8   | 10   | 6     | 1   | 1     | 1   | 3      |
| Add    | 7   | 74  | 4    | 4   | 5   | 7    | 25    | 2   | 2     | 0   | 3      |
| Skim   | 25  | 128 | 21   | 7   | 43  | 36   | 76    | 16  | 3     | 0   | 4      |
| Click  | 36  | 45  | 12   | 4   | 40  | 91   | 121   | 1   | 2     | 3   | 17     |
| Exp    | 1   | 1   | 13   | 0   | 1   | 10   | 3     | 2   | 0     | 0   | 0      |
| Pause  | 8   | 4   | 0    | 2   | 0   | 6    | 5     | 0   | 0     | 0   | 2      |
| Rec    | 1   | 1   | 0    | 1   | 0   | 0    | 2     | 1   | 0     | 0   | 0      |
| Search | 5   | 5   | 2    | 1   | 18  | 8    | 14    | 1   | 1     | 0   | 3      |

z-values  
> 1.96



Yule's Q Values  
≥ .30

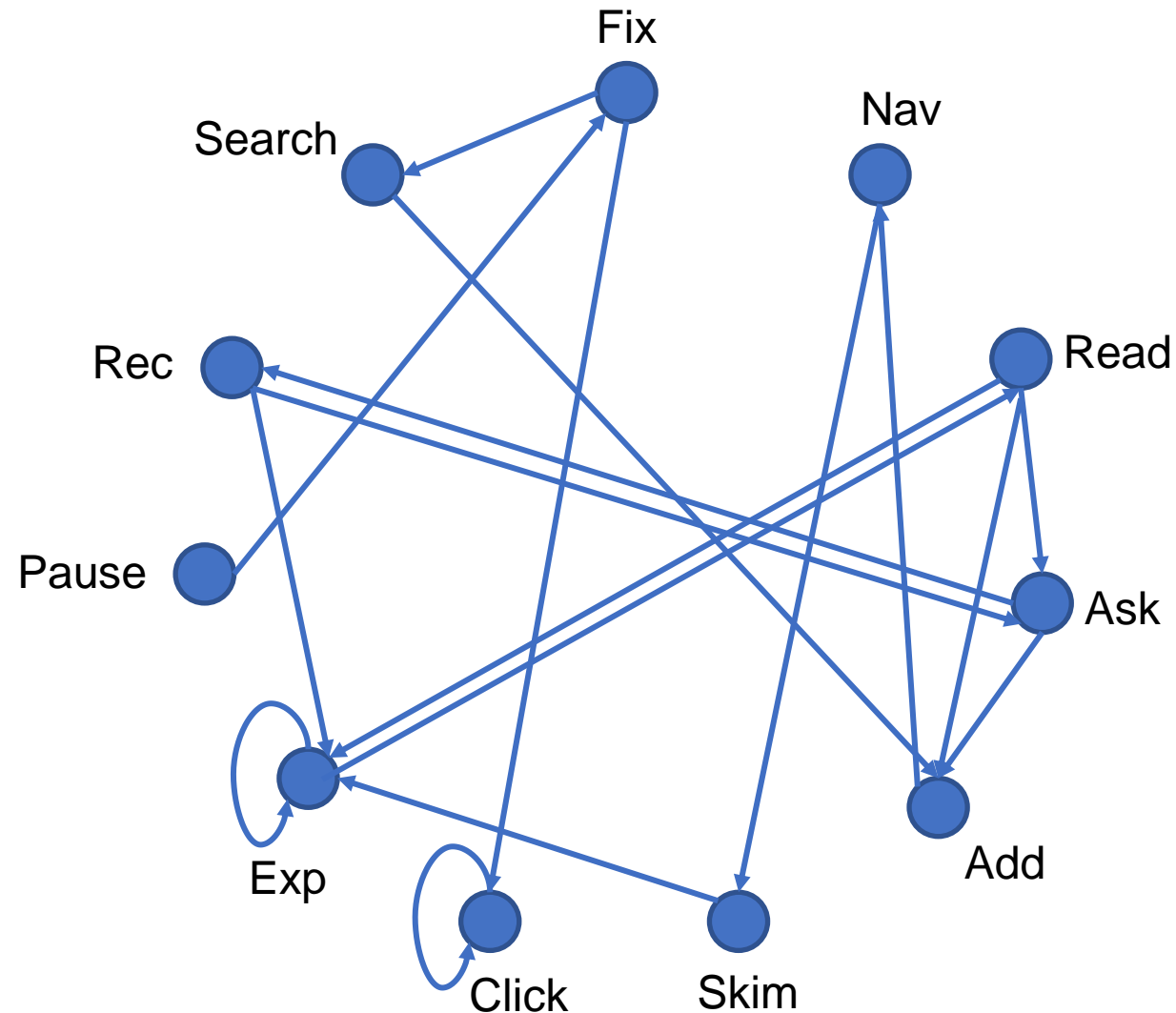


|        | Fix   | Nav   | Read  | Ask   | Add   | Skim  | Click | Exp   | Pause | Rec   | Search |
|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| Fix    | -0,60 | -3,95 | 0,92  | -0,05 | -1,84 | -0,07 | 3,18  | -1,64 | -0,81 | 0,80  | 7,15   |
| Nav    | -3,17 | 0,96  | -0,50 | 0,20  | 4,94  | 6,45  | -6,06 | -2,83 | -0,39 | 1,11  | -3,23  |
| Read   | -0,02 | -1,62 | -1,59 | 2,20  | 6,27  | -2,27 | -0,84 | 3,71  | -1,02 | 1,69  | -0,81  |
| Ask    | -0,65 | -1,58 | -1,24 | -0,96 | 3,05  | 0,78  | -0,93 | 0,37  | 0,52  | 2,39  | 1,53   |
| Add    | -1,50 | 6,92  | -0,43 | 0,62  | -1,76 | -4,56 | -0,55 | -0,25 | -0,05 | -0,71 | -0,72  |
| Skim   | -0,73 | 2,94  | 2,44  | -0,42 | 3,46  | -5,59 | -0,13 | 4,29  | -1,24 | -1,25 | -2,63  |
| Click  | 1,23  | -8,25 | -0,53 | -1,72 | 2,53  | 2,04  | 6,03  | -2,49 | -1,79 | 1,71  | 1,49   |
| Exp    | -0,97 | -3,22 | 11,40 | -0,85 | -0,94 | 1,61  | -1,61 | 1,98  | -0,71 | -0,33 | -1,04  |
| Pause  | 4,22  | -1,67 | -1,02 | 1,82  | -1,51 | 0,20  | -0,37 | -0,71 | -0,66 | -0,31 | 1,19   |
| Rec    | 0,80  | -0,68 | -0,48 | 2,39  | -0,71 | -1,25 | 0,71  | 2,76  | -0,31 | -0,14 | -0,46  |
| Search | 0,21  | -3,53 | -0,10 | -0,27 | 6,81  | -1,31 | 0,51  | -0,04 | 0,11  | -0,46 | 0,79   |

|        | Fix   | Nav   | Read  | Ask   | Add   | Skim  | Click | Exp   | Pause | Rec   | Search |
|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| Fix    | -0,03 | -0,37 | 0,09  | 0,00  | -0,58 | 0,00  | 0,30  | -1,00 | -0,16 | 0,19  | 0,73   |
| Nav    | -0,27 | 0,17  | -0,19 | 0,05  | 0,06  | 0,38  | -0,42 | -0,72 | 0,26  | 0,09  | -0,58  |
| Read   | 0,06  | -0,17 | -1,00 | 0,53  | 0,52  | -0,44 | -0,14 | 0,69  | -1,00 | 0,54  | -0,38  |
| Ask    | -0,16 | -0,24 | -1,00 | -1,00 | 0,33  | 0,15  | -0,20 | 0,19  | 0,47  | 0,69  | 0,43   |
| Add    | -0,24 | 0,60  | -0,21 | 0,18  | -0,56 | -0,67 | -0,06 | -0,09 | 0,24  | -1,00 | -0,21  |
| Skim   | 0,00  | 0,28  | 0,20  | -0,07 | 0,02  | -0,46 | -0,01 | 0,62  | -0,10 | -1,00 | -0,57  |
| Click  | 0,21  | -0,52 | -0,19 | -0,40 | -0,06 | 0,14  | 0,37  | -0,79 | -0,35 | 0,30  | 0,21   |
| Exp    | -0,39 | -0,83 | 0,90  | -1,00 | -0,60 | 0,30  | -0,44 | 0,60  | -1,00 | -1,00 | -1,00  |
| Pause  | 0,71  | -0,35 | -1,00 | 0,58  | -1,00 | 0,05  | -0,09 | -1,00 | -1,00 | -1,00 | 0,41   |
| Rec    | 0,46  | -0,28 | -1,00 | 0,80  | -1,00 | -1,00 | 0,30  | 0,84  | -1,00 | -1,00 | -1,00  |
| Search | 0,12  | -0,59 | -0,13 | -0,12 | 0,57  | -0,24 | 0,08  | -0,02 | 0,29  | -1,00 | 0,23   |

# Lag sequential analysis (LSA)

Fix → Click  
 Fix → Search  
 Nav → Skim  
 Read → Ask  
 Read → Add  
 Read → Exp  
 Ask → Add  
 Ask → Rec  
 Add → Nav  
 Skim → Exp  
 Click → Click  
 Exp → Read  
 Exp → Exp  
 Pause → Fix  
 Rec → Ask  
 Rec → Exp  
 Search → Add



# Formal Concept Analysis

- Formal Kontext  $K := (G, M, I)$ 
  - $G$ ...egenstände (objects)
  - $M$ ...erkmale (attributes)
  - $I$ ...ncidence relation (binary assignments between  $G$  and  $M$ )
- $K$  as Crosstable

## Example: Person 02

Processes

|     | Fix | Nav | Read | Ask | Add | Skim | Click | Exp | Pause | Rec | Search |
|-----|-----|-----|------|-----|-----|------|-------|-----|-------|-----|--------|
| WC1 | 2   | 1   | 0    | 0   | 2   | 3    | 1     | 0   | 1     | 0   | 0      |
| WC2 | 1   | 15  | 1    | 0   | 5   | 16   | 2     | 0   | 0     | 0   | 0      |
| WC3 | 0   | 7   | 4    | 0   | 2   | 4    | 2     | 0   | 2     | 0   | 0      |
| WC4 | 0   | 2   | 0    | 0   | 0   | 0    | 1     | 0   | 0     | 3   | 0      |
| TB1 | 0   | 0   | 0    | 0   | 1   | 2    | 1     | 0   | 1     | 0   | 0      |
| TB2 | 0   | 6   | 0    | 0   | 2   | 6    | 2     | 0   | 0     | 0   | 0      |
| TB3 | 2   | 4   | 6    | 0   | 3   | 1    | 2     | 3   | 1     | 0   | 0      |
| TB4 | 1   | 0   | 0    | 0   | 1   | 1    | 0     | 0   | 0     | 0   | 0      |
| IS1 | 1   | 1   | 0    | 0   | 1   | 1    | 1     | 0   | 0     | 0   | 0      |
| IS2 | 0   | 10  | 0    | 0   | 5   | 0    | 6     | 0   | 0     | 0   | 0      |
| IS3 | 2   | 7   | 0    | 0   | 1   | 6    | 1     | 0   | 1     | 0   | 0      |

Tasks



Processes

|     | Fix | Nav | Read | Ask | Add | Skim | Click | Exp | Pause | Rec | Search |
|-----|-----|-----|------|-----|-----|------|-------|-----|-------|-----|--------|
| WC1 | X   | X   |      |     | X   | X    | X     |     | X     |     |        |
| WC2 | X   | X   | X    |     | X   | X    | X     |     |       |     |        |
| WC3 |     | X   | X    |     | X   | X    | X     |     | X     |     |        |
| WC4 |     | X   |      |     |     |      | X     |     |       | X   |        |
| TB1 |     |     |      |     | X   | X    | X     |     | X     |     |        |
| TB2 |     | X   |      |     | X   | X    | X     |     |       |     |        |
| TB3 | X   | X   | X    |     | X   | X    | X     | X   | X     |     |        |
| TB4 | X   |     |      |     | X   | X    |       |     |       |     |        |
| IS1 | X   | X   |      |     | X   | X    | X     |     |       |     |        |
| IS2 |     | X   |      |     | X   |      | X     |     |       |     |        |
| IS3 | X   | X   |      |     | X   | X    | X     |     | X     |     |        |

Tasks

- Flexibility: all kinds of objects and attributes, dichotomization based on z-values, Median-split...



# Formal Concept Analysis

- Derivation Operators for each  $A \subseteq G$  and  $B \subseteq M$ :

$$A \mapsto \underline{A}' := \{m \in M \mid gIm \text{ for all } g \in A\},$$

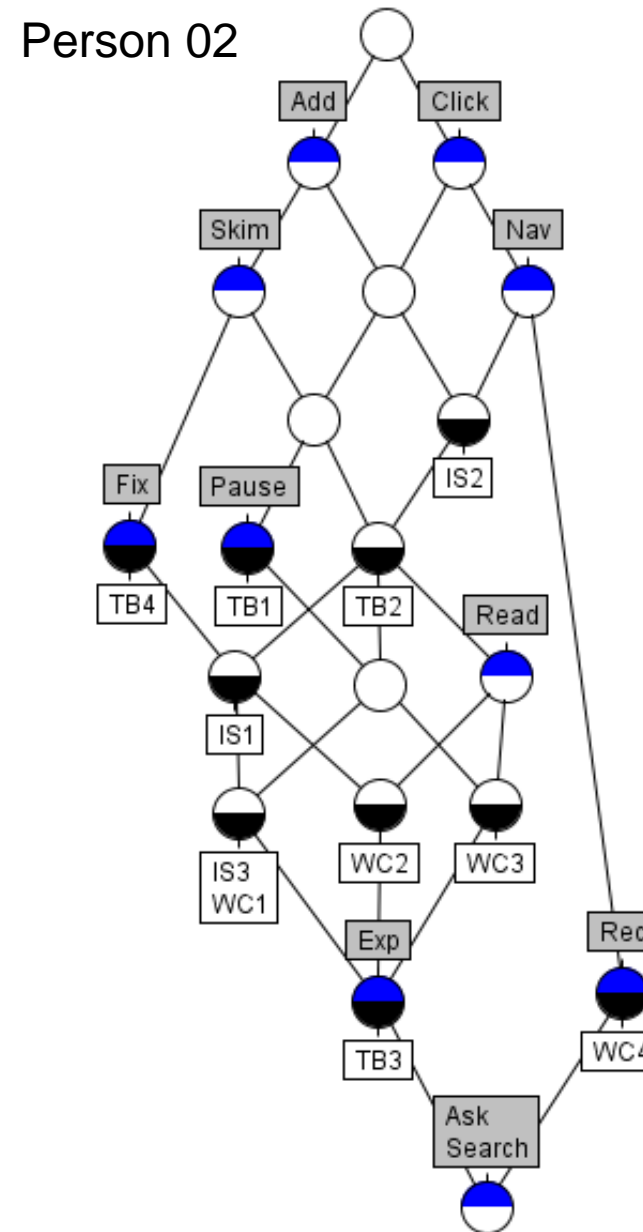
$$B \mapsto \underline{B}' := \{g \in G \mid gIm \text{ for all } m \in B\}.$$

- A formal concept is a pair  $(A, B)$  that fulfills:

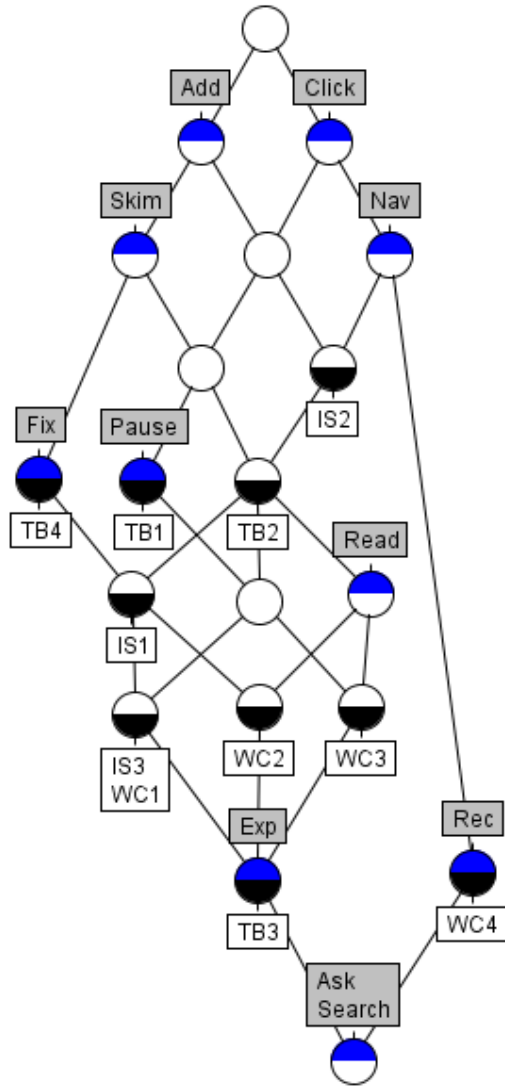
$$A' = B \text{ and } B' = A$$

$A$  (extension),  $B$  (intension)

- Concept lattice: set of all formal concepts, ordered by 'sub-super-concept relation'

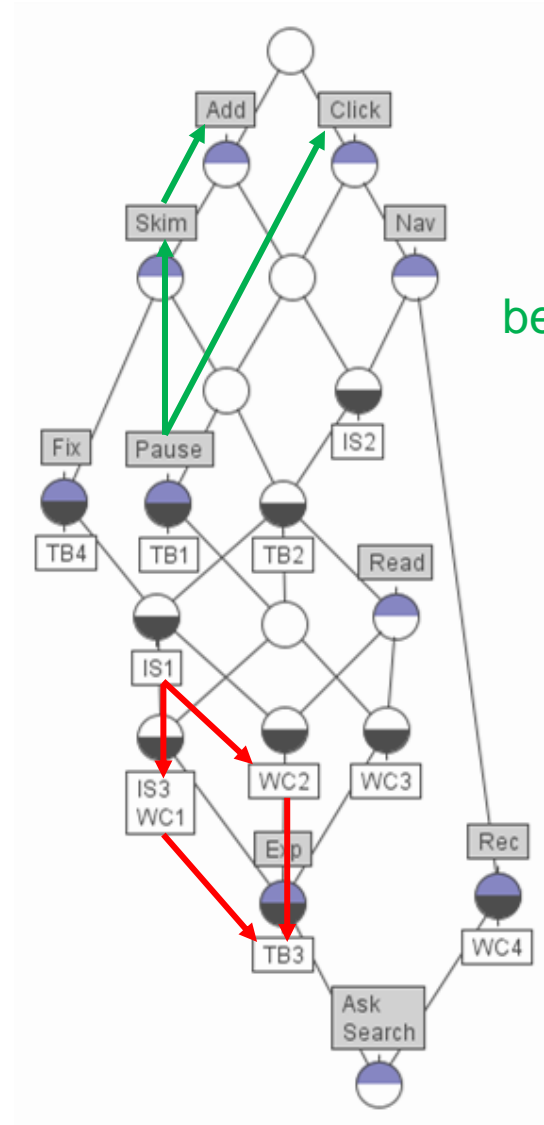
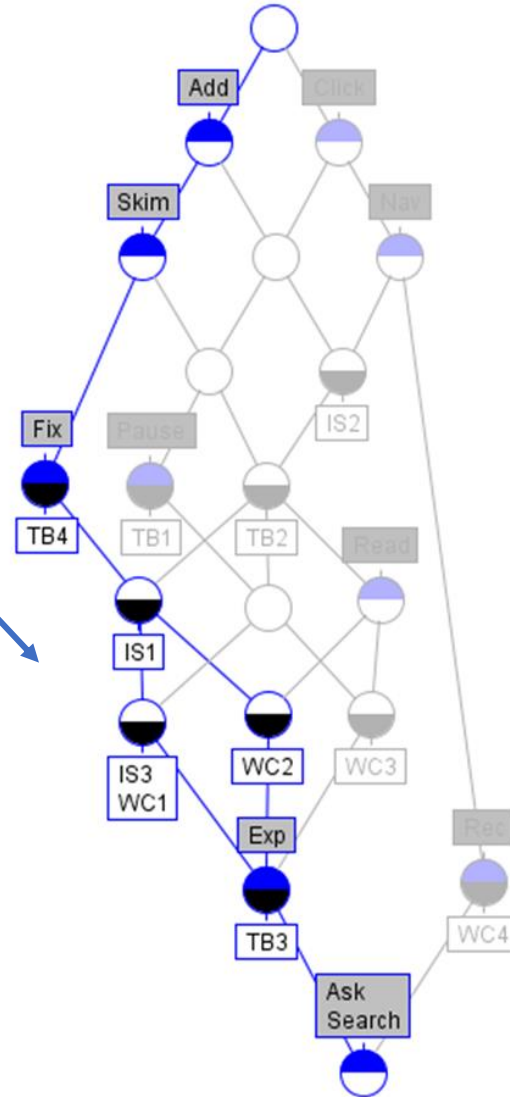


# Formal Concept Analysis



intension

extension

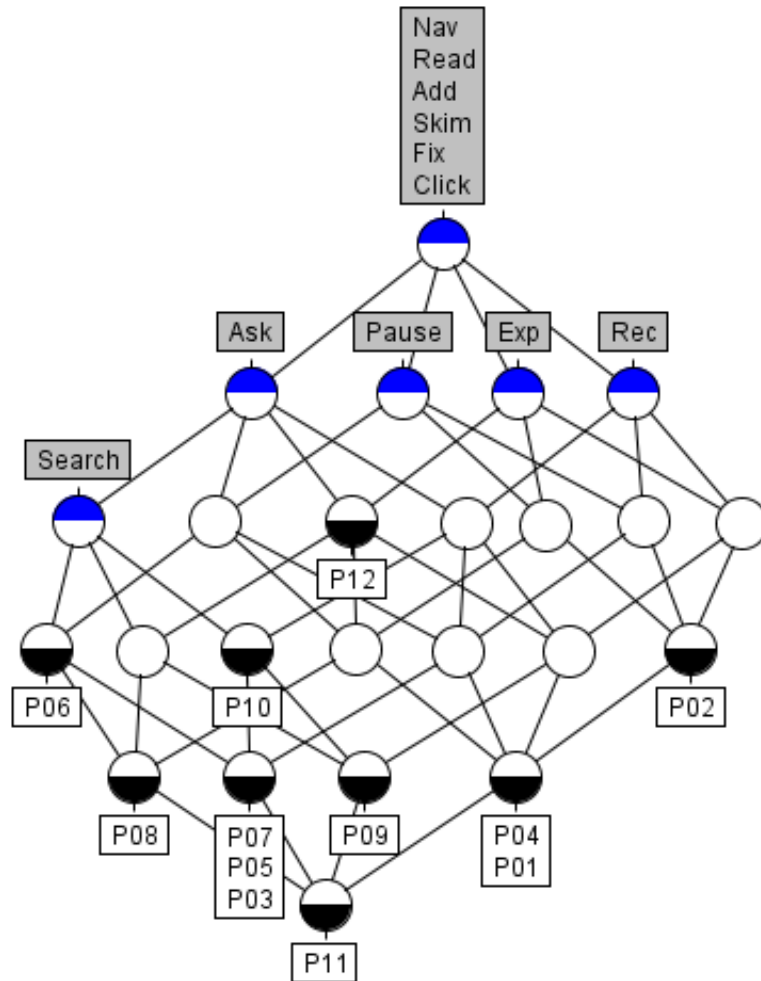


Dependencies  
between processes

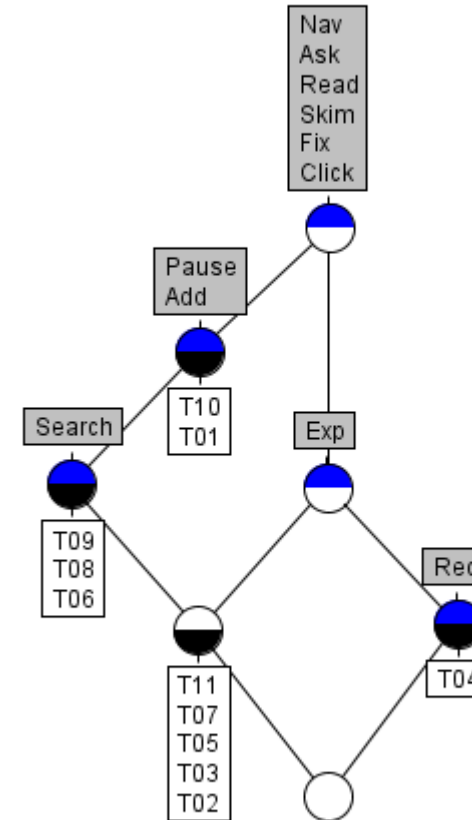
Dependencies  
between tasks

{(TB4, IS1, IS3, WC1, WC2, TB3), (Fix, Skim, Add)}

# Formal Concept Analysis – Overall



Comparing Persons



Comparing Tasks

# Current work and Outlook

- Systematic comparison between different methods is work in progress
  - Identifying strengths and weaknesses (questions that can be answered or not)
- Clustering / Comparing tasks and persons
- Elaborating interventions & design adaptations in case of to support users (e.g. repeated loops)
- In the end, only unsupervised usage possible, thus, automatic assessment of cognitive states required (e.g. Lengauer et al. 2023)



Thank you very much for your attention!

Let`s discuss...

