Revealing Differences in Designer‘s and Users‘Perspectives:

A Tool-supported Process for Visual Attention Prediction for Designing HMIs for Maritime Monitoring Tasks

Sebastian Feuerstack
Bertram Wortelen

OFFIS
Institute for Information Technology
Oldenburg, Germany

Email: feuerstack@offis.de

Monitoring Systems

Why do we need to learn about the monitoring behavior?

- Monitoring is done *to observe a system state in order to predict future states of the system*.

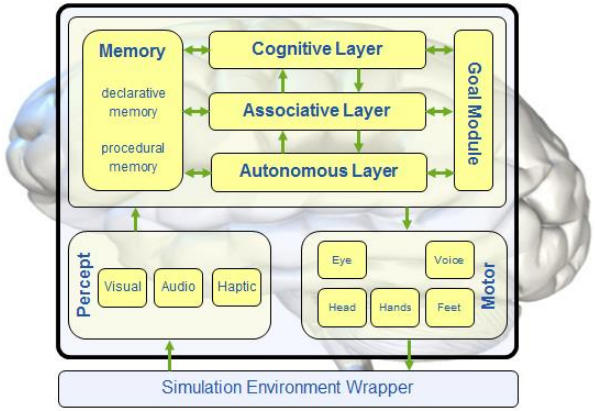
- Monitoring happens for instance while: driving a car, flying a plane, or
  - steering a vessel:
    - Monitoring tasks consume most of the time spent
    - 70%-80% of accidents happen because of missing access to information

Monitoring Behavior

Ways to learn about the monitoring behavior of a user

1. *Eye-Tracking Technology*
   - Trustworthy, noisy data: PDT, Traces
   - Considers system dynamics
   - Requires Prototype, realistic Setup, several Participants, High Effort (Time + Costs)

2. *Attention Prediction by using Cognitive Modelling*
   - Comparative data: PDT
   - „Abstract“, mostly static system
   - No prototype, few experts, low effort
   - Model can be inspected
   - „Tricky to use“



Attention Prediction

by running a user model in a cognitive architecture

- A cognitive architecture can be understood as a
  - „generic interpreter“ that
  - executes formalized procedures of a human operator
  - In a physiological and psychological plausible models.

- Adaptive Information Expectancy Model (Wortelen, 2014)
  - Probability ***P*** of switching to goal ***g*** among a set of goals:

$$P(g) = \frac{u_g}{\sum_{g_i \in G} u_{g_i}} \cdot \frac{v_g}{\sum_{g_i \in G} v_{g_i}}$$

u – expected new information, ***v*** – value of information… of an information source (IS)

Basic Research Questions

for performing a qualitative study

Are non-experts in cognitive modelling able to generate visual attention predictions?

*H_1: Users without specific prior knowledge **are able to use the HEE** and end up with results **in a reasonable amount** of time*

*H_2: The **variations** between the models specified by the participants are small*

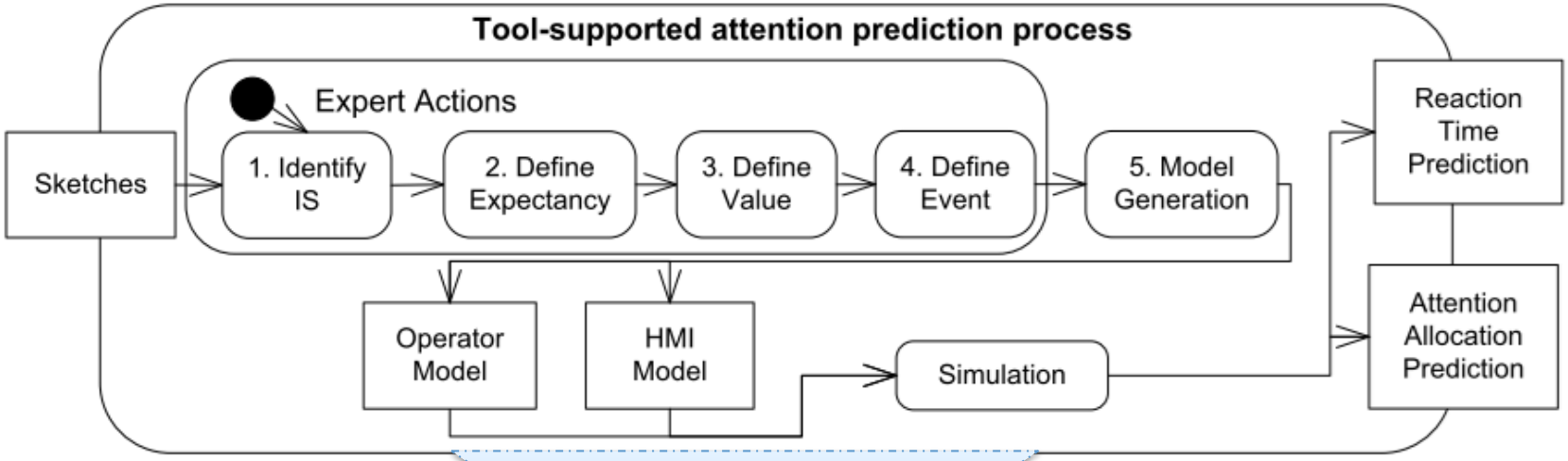
How do helpful visualizations of the results look like and for what are they good for?

H_3: The result visualization of the HEE is clear:

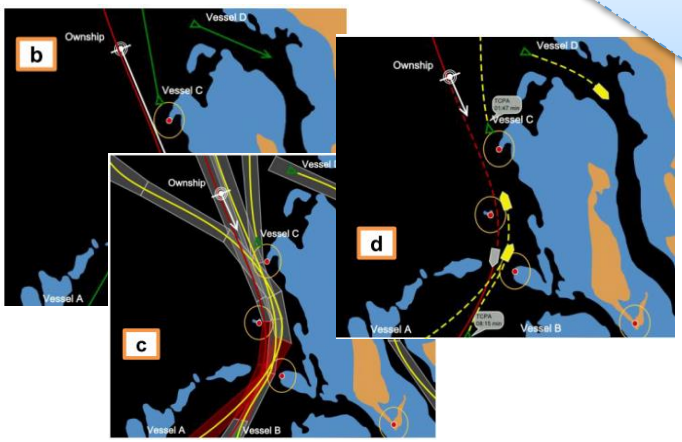
- *H_{3a}: for a **pie chart** -> average attention allocation prediction*
- *H_{3b}: for a **heatmap** -> average attention allocation distribution*
- *H_{3b}: for a **histogram** -> avg. reaction time prediction*

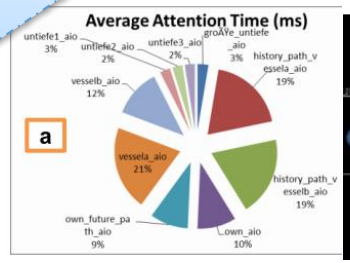
Expectancy and Value Definition

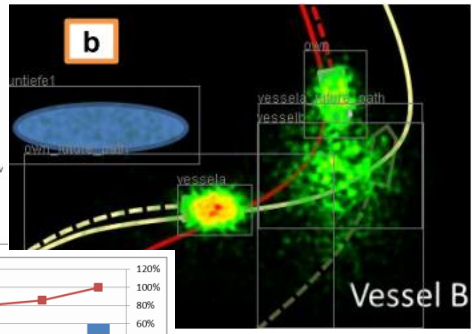
by following a structured, tool supported process

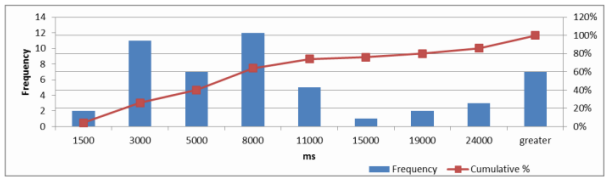


Tool-supported Process



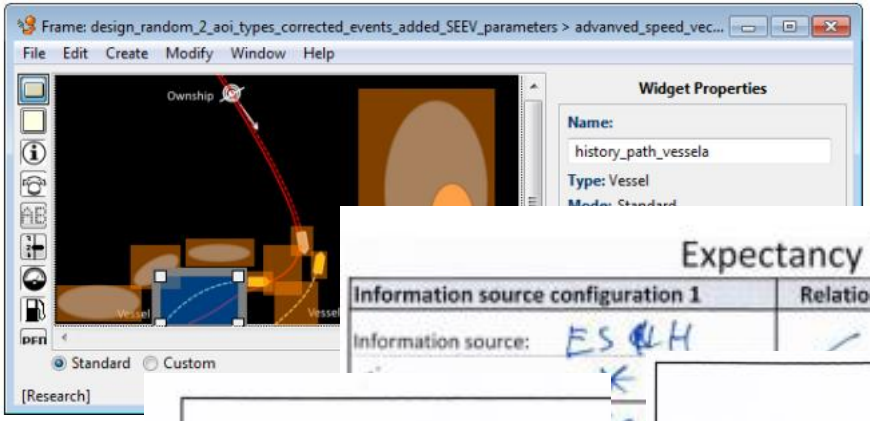


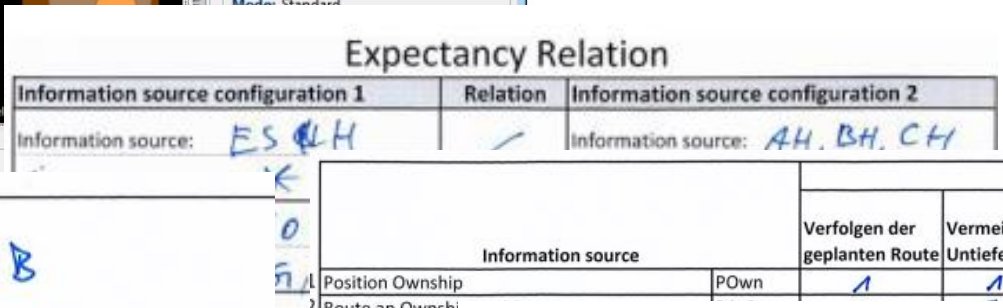


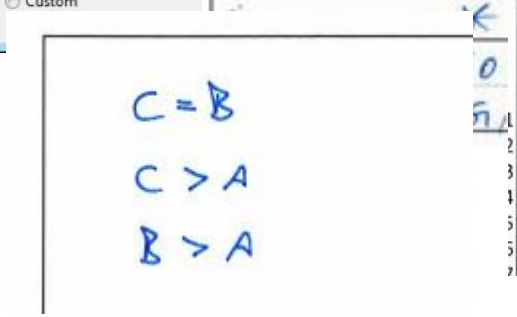


Demonstration Video

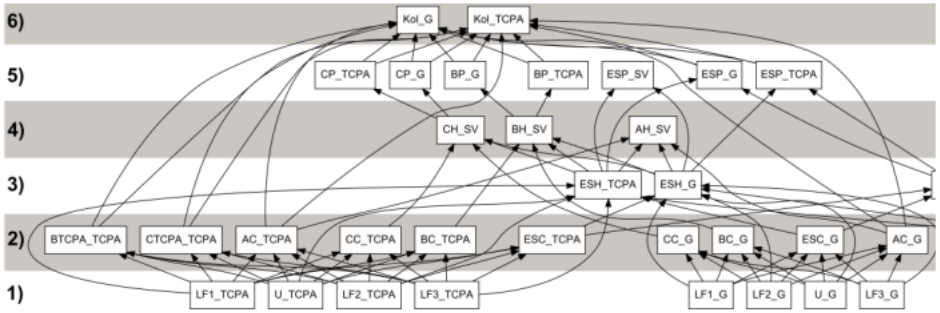
…of the entire tool supported avg. attention prediction process







Information source		Task: Verfolgen der geplanten Route	Task: Vermeiden von Untiefen (blau)	Task: Vermeidung von gefährlichen Schiffsannäherungen
Position Ownship	POwn	1	1	1
Route an Ownshi				
Position, Geschw				
Position, Geschw				
Position, Geschw				
Position und Kurs				



Explorative Study

The study setup

- *Four Subject Matter Experts*
  - Cognitive Modelling Expert
  - Interface Designer that created the designs
  - Expert in Analyzing Situation Awareness
  - Maritime Domain Expert (ship master)
- All Experts (where video-taped)
  - received a short scripted introduction (~10 min)
  - performed the entire process (questions allowed)
  - where asked for feedback after each step
  - analyzed the results (visualizations)

Results

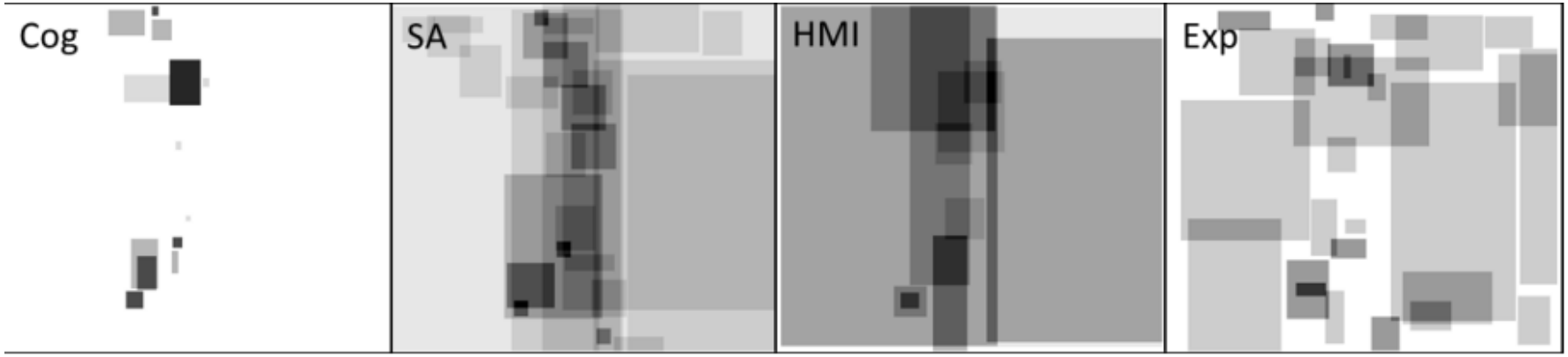
*about **required modelling time** + prior knowledge required*

Subject	IS Identification		Expectancy		Relevance		Entire Modelling Time	Entire study
Cog	3	23	6	16	1	3	42	94
SA	6	70	3	55	1	7	132	112
HMI	5	52	2	53	1	7	112	105
Exp	6	90	3	54	1	16	160	231

- *Modelling Mean Time: 2:02h*
  - Cog. Exp. felt most familar, had fewest IS (18)
  - Sit. Awareness Exp. had most IS marked (47)
  - Maritime Exp. commented a lot for IS (90 min)
- *All experts were able to get results in a reasonable amount of time.*

Results

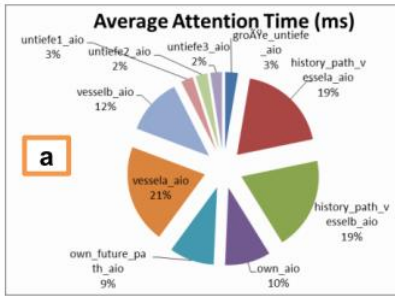
about model variations

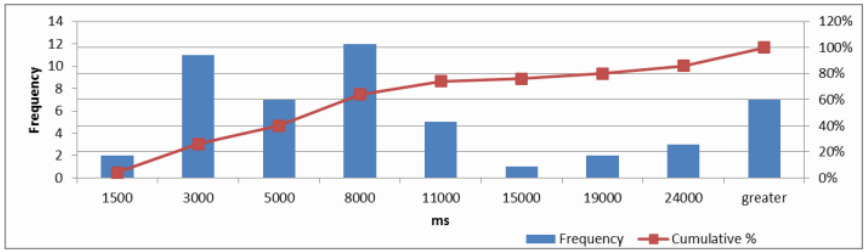


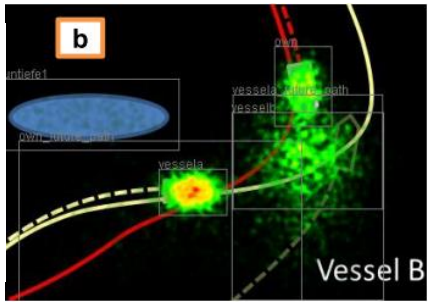
- *130 Information Sources over 3 designs*
  - 4 identical: beacons, ownship pos, high danger arega
  - 8 marked different, 26 only marked by one expert,
  - Model similarity measure: RSID
    - 10 most similar have clear boundaries
    - 11th most similar area of danger w/o clear borders.
- We found no support for model similarity

Results

understandability of result visualization







- *Pie chart*
  - How does an optimal attention distribution look like?
    - 3 focus on a few IS only vs. HMI balanced distrib.
- *Histogram*
  - Figured out to be complicated, even with example
- *Heatmap*
  - Matched expectencies, all found arguments for their prefered design.

12 Conclusions

based on the qualitative study

- Tool-based attention distribution predictions can be generated even by non-experts in cognitive modelling in a reasonable short amounts of time

- Information Source Markup vary -> Predictions as well
  - Does not affect the user's expectation
  - Variance affected by HMI with few element boundaries

- Visualizations
  - A pure attention distribution presented as a pie-charts has little value
  - Histograms were hard to understood for the audience
  - Heatmaps were easily understood and support analysis
    - What can a HMI designer learn from the operator's heatmap?

Questions ?

Thanks for your attention

Sebastian Feuerstack
feuerstack@offis.de