
The Sixth Sense of an Air Traffic Controller

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Motivation: Human Factors Improvement

- Humans are a limiting factor – if not sufficiently supported
- Drastic improvements should be achievable utilizing more “human senses”
 - More bandwidth between human and machine
 - Possible safety net through comparison of different “senses”
- Prediction through subconscious body language
 - Can we depict repetitive patterns?
 - Can we predict “good” and “bad” decisions measureable?



Introduction

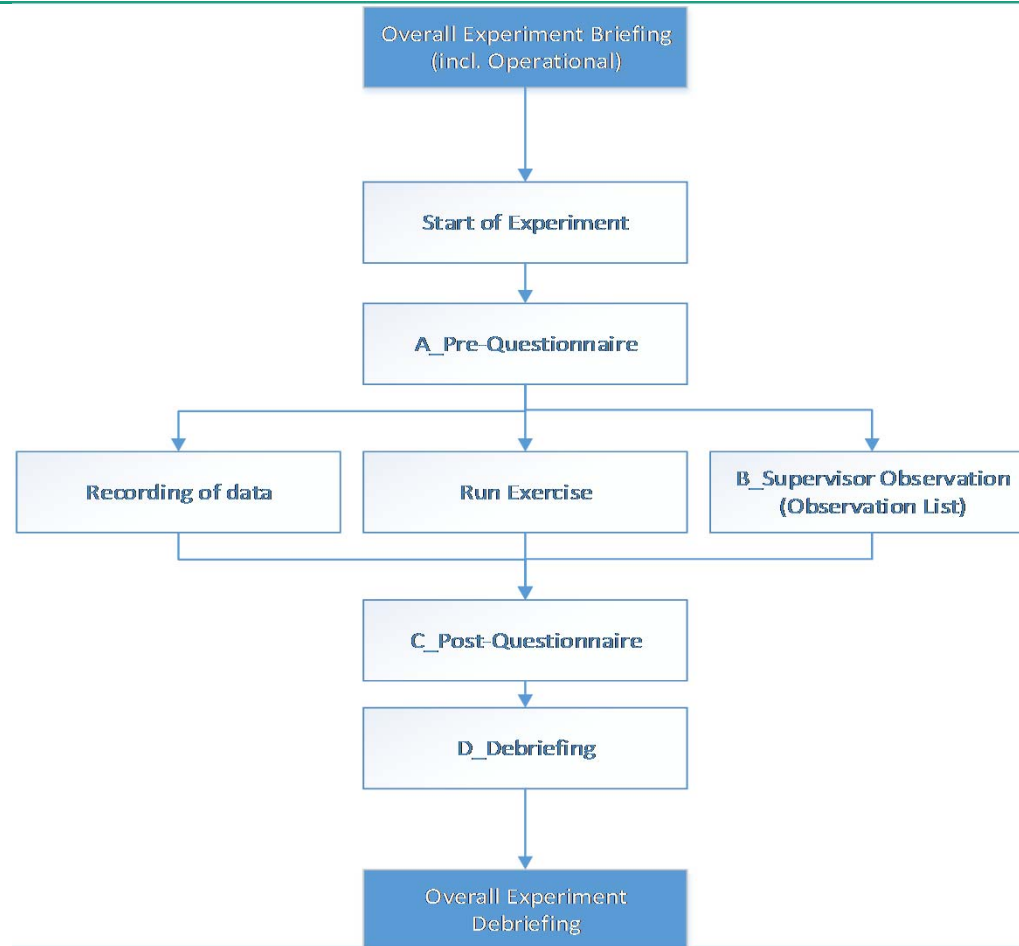
- When working with an ATM system
can the user's body language/choices
provide valuable cognitive information
- To uncover hidden patterns
that will allow us
- To distinguish between “good/bad” (erroneous)
inputs/interactions
and ultimately avoid mistakes /bad decisions



EEC - Eurocontrol Experimental Centre
courtesy of Eurocontrol

Experiment Set-up

Experimental Workflow



Our Hypothesis

The algorithms of the 6th Sense Module should be tested by answering the following hypotheses:

Hypothesis H1: It is possible to detect situations in which the operator tends to make bad decisions by analysing user-input and user-tracking data

■ **Hypothesis H2:** The module is able to identify good and bad workflow patterns.

Workflow patterns in H2 are sub-sequences of actions the controller performs. These workflow patterns might vary between controllers. H1 refers to the decision a controller makes in a single step of the workflow.

Experiment Set-up



■ Exercise 1

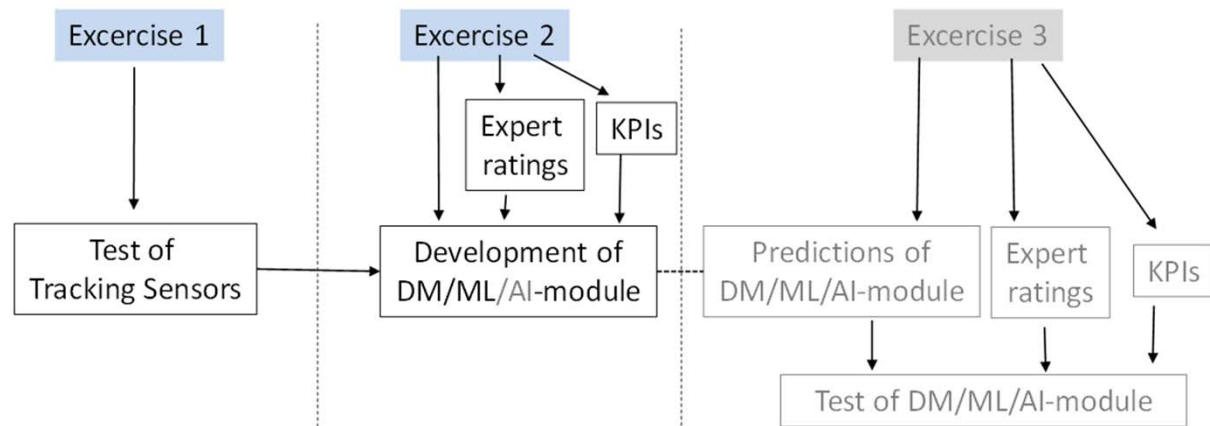
- Sensor hardware tested, data acquisition pipeline established

■ Exercise 2 part 1 (01.12.2014 - 02.12.2014) – 4 ATCOs

- professional air traffic controllers and first real test of setup

■ Exercise 2 part 2 (05.02.2015) – 4 ATCOs

- observer and supervisor notes integrated in the framework
- environmental sensors added



Experiment Set-up

Scenario

■ Hamburg Airport Tower Scenario:

- Simulation prepared for approx. 60 min.
- Arrivals are automatically simulated until touchdown. (no change of route)
- Departures are controlled until take off.
- No Runway change is foreseen within the simulation
- Taxiway Routes can be selected by the operator.

■ Configurations during the experiment:

- Arrival Runway: 23
- Departure Runway: 33
- Arrivals: 31 flights
- Departures: 27 flights



Experiment Set-up

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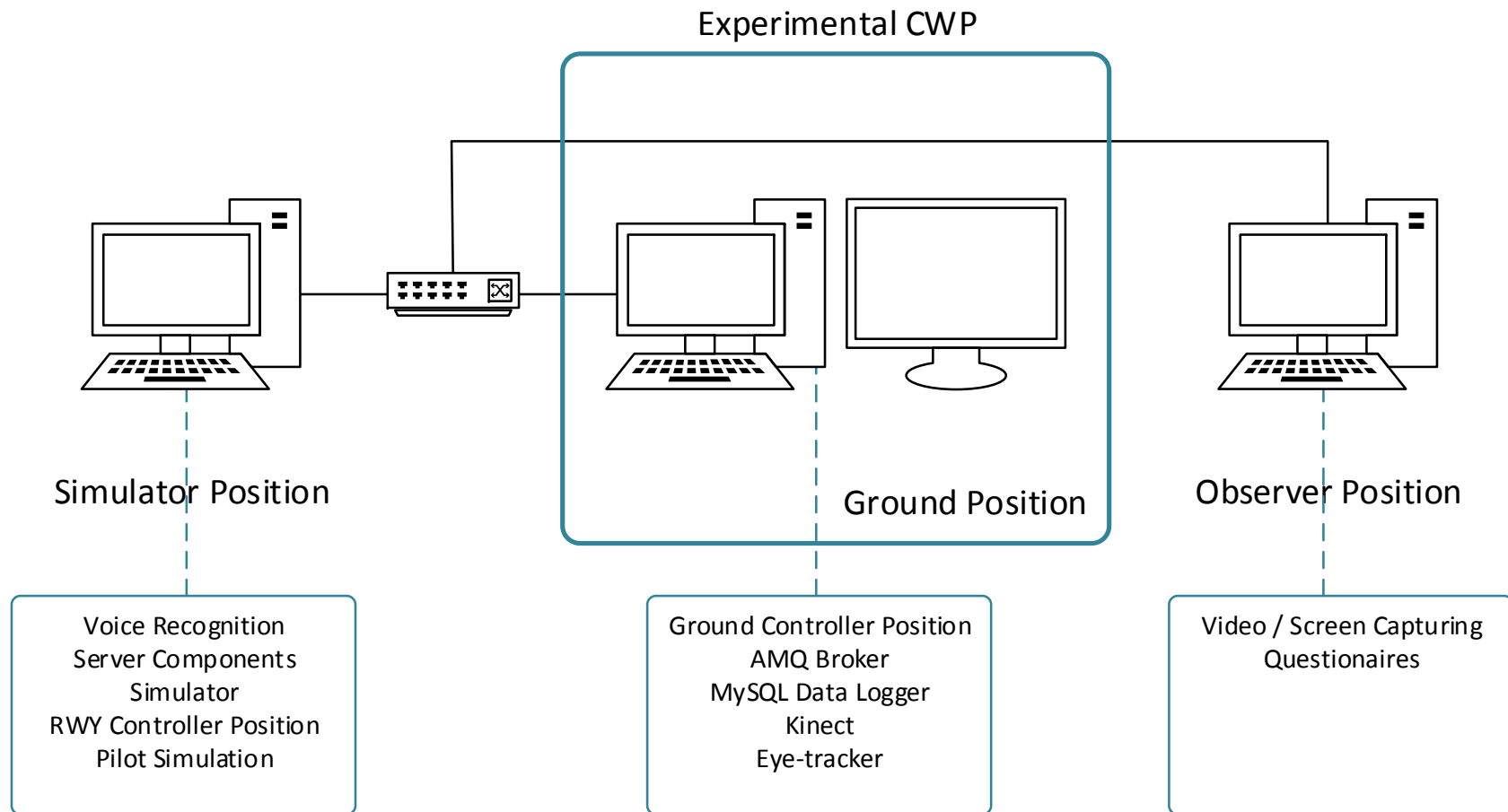


Any other workflow would be fine, too

- Area Control
- TMA
- Airport

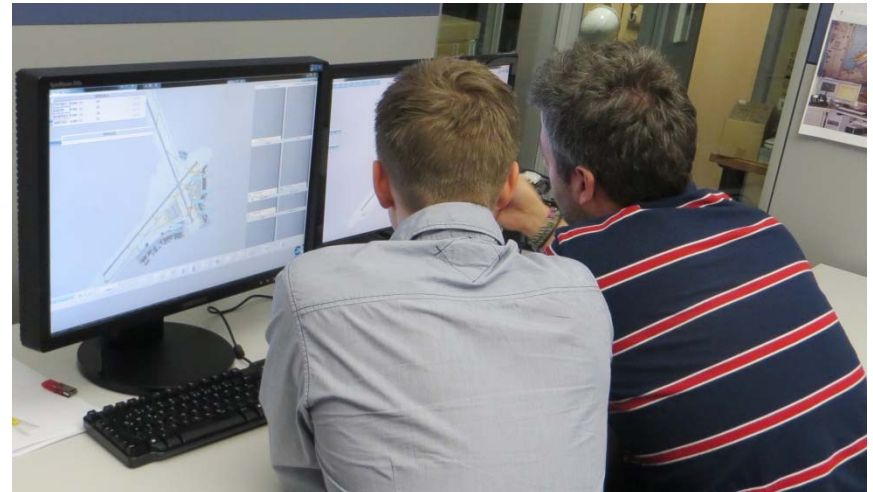
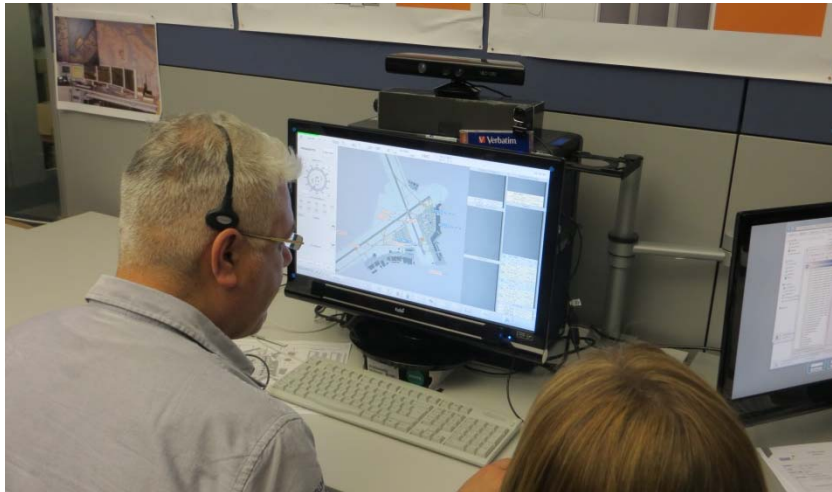
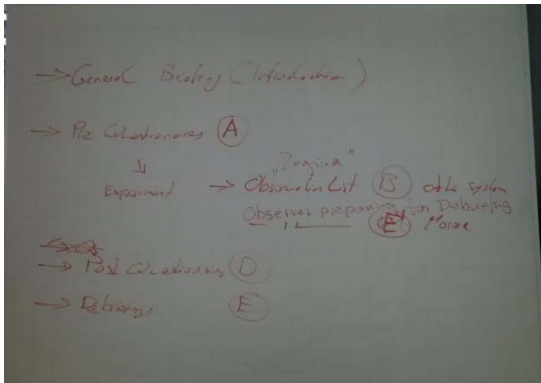
Experiment Set-up

Working Position



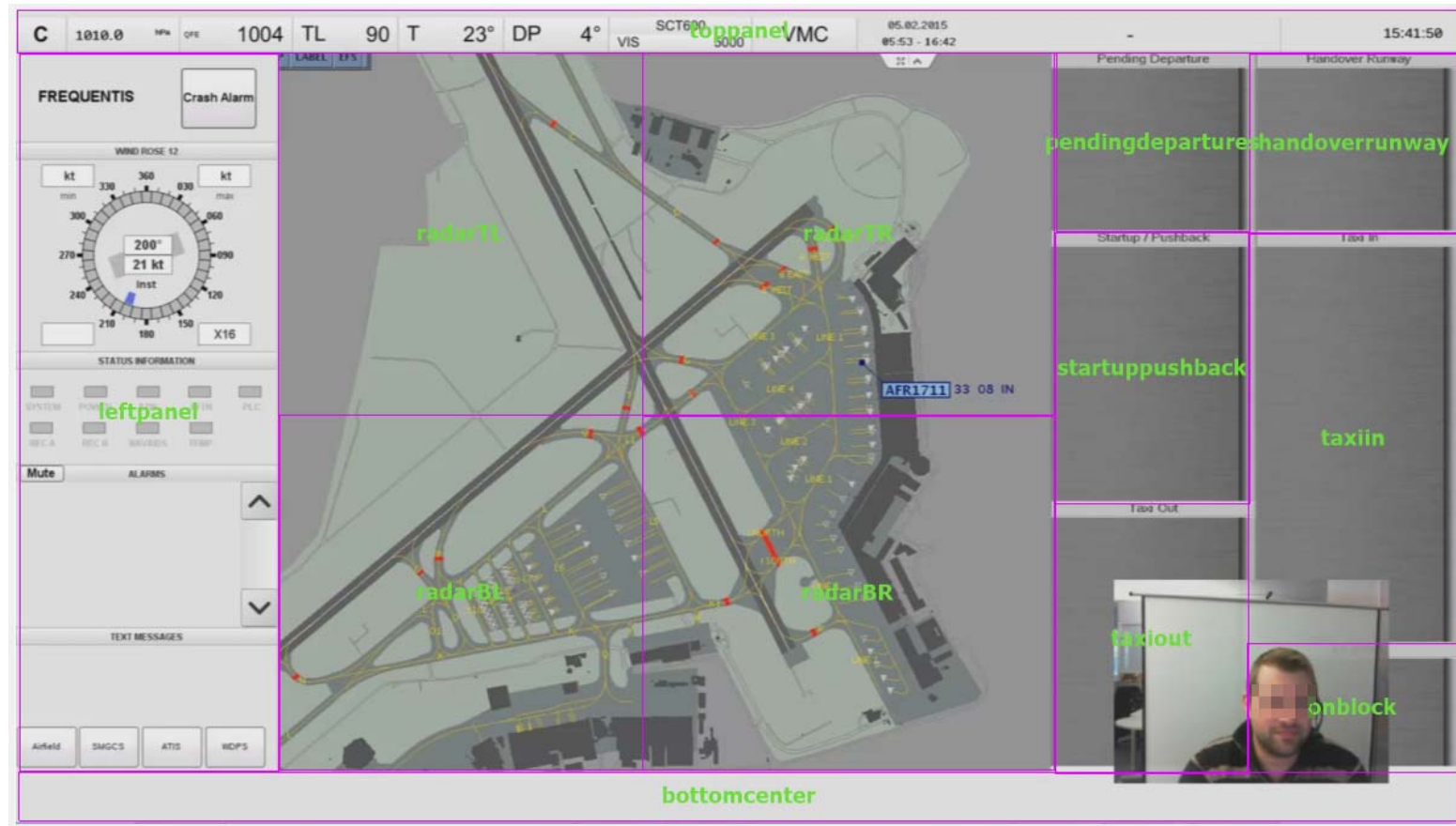
Experiment

From Plan to execution



Experiment

From Plan to Execution



Areas of Interest (AOI) in Ground Control Simulator

Experiment

From Plan to Execution



Observation
&
Debriefing



The collected Data

Variables	Topics (Datasets)	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8	Total Events by Topic	Description
3	Supervisor & Observer	51	65	13	123	91	91	107	152	693	Reports from Supervisors and Observers
3	StressLevel	6	6	6	6	6	6	7	6	49	Stress Level reports (from users)
42	FlightObject	616	420	57	436	302	241	340	434	2846	Flight Information
6	Selections	420	302	17	211	197	149	209	268	1773	Strips Selections
10	Eye	0	0	53	169	9097	61770	72534	68116	211739	Eye Tracker
4	GlobalMouse	0	72891	2929	79618	3844	12700	7588	8082	187652	Mouse UI Hook
7	Mouse	3046	1929	110	1290	916	1838	1266	1915	12310	Mouse Listener
23	Kinect	27351	0	0	0	7561	0	0	0	34912	Kinect Listener
12	Voice	1014	1160	36	1242	256	899	1126	1587	7320	Voice Listener
4	Waspmote	0	0	0	0	1807	2754	3041	3376	10978	Waspmote Listener
12	Heart Rate Measurements	0	2978	2274	5347	0	4512	0	5184	20295	Heart Rate Events Collected
13	Eye AOI (Fixations, Gazes, Saccades)	0	0	0	0	715	1625	3396	3767	8788	Eye Tracking Areas of Interest
13	Mouse AOI (Fixations, Gazes, Saccades)	0	2217	0	2325	62	2729	1002	1083	9418	Mouse Tracking Areas of Interest
152	<= Total Number of Variables	32504	81968	5495	90767	24139	89314	90616	93970	508773	Total Data Collected in 2 experiments
58	<= Total Number of Airplanes	Number of Events								Number of Total Events Collected	
27	<= Departures										
31	<= Arrivals										

The collected Data

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Simple Metrics and Data Exploration

- Decision on topics and metrics, ranking
- Based on data availability, completeness, data quality and relevance
- The selected topics were:
 - Mouse
 - Observations
 - Selections
 - Selection and Stress level
 - Voice
 - Workload Metrics
 - Eye Mouse AOI
 - Heart Measurements

A word on Observations

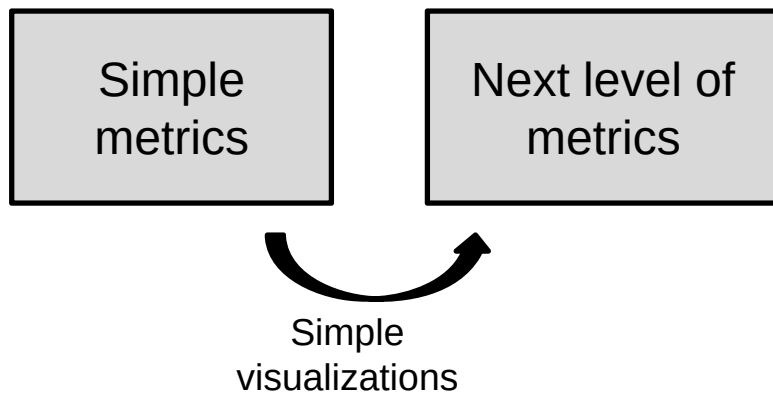
- Observation list created from video recordings
 - Side remark for lessons learnt: next time add a self-assessment part

Timestamp	Message type	Message	Positive / Negat	Category	Origin	related Time Stamp	Impact
01.12.2014 16:03:23	MP	SWR560 waits after crossing	Negative	After Crossing / Queuing	user1	01.01.1900 00:16:41	-3
01.12.2014 16:04:20	MP	TRA770 change route to IN.	Positive	Taxiway Optimisation	user1	01.01.1900 00:17:38	5
01.12.2014 16:09:14	MP	SWR560 now moving again	Neutral	Taxiway Optimisation	user1	01.01.1900 00:22:32	0
01.12.2014 16:10:52	MP	Problem which could occur to a blocking situation BAW964 and AMC 2668	Negative	Blocking Situation which delays other plane /	user1	01.01.1900 00:24:10	-5
01.12.2014 16:14:04	MP	Arrival queue 3	Negative	Arrival Queue greater 3	user1	01.01.1900 00:27:22	-3
01.12.2014 16:14:16	MP	arrival queue solved	Positive	Arrival Queue greater 3	user1	01.01.1900 00:27:34	3
01.12.2014 16:23:21	MP	Arrival queue 3	Negative	Arrival Queue greater 3	user1	01.01.1900 00:36:39	-3
01.12.2014 16:24:41	MP	Ber117D waiting after crossing	Negative	After Crossing / Queuing	user1	01.01.1900 00:37:59	-3
01.12.2014 16:25:43	MP	arrival queue solved	Positive	Arrival Queue greater 3	user1	01.01.1900 00:39:01	3
01.12.2014 16:26:24	MP	Ber117D solved	Positive	After Crossing / Queuing	user1	01.01.1900 00:39:42	3
01.12.2014 16:26:58	H-User needs help	difficulties with the UI	HelpX	UI	user1	01.01.1900 00:40:16	-3

Approach to guide our Analysis

Simple
metrics

Approach to guide our Analysis



Approach to guide our Analysis

Simple
metrics
(Table 3)

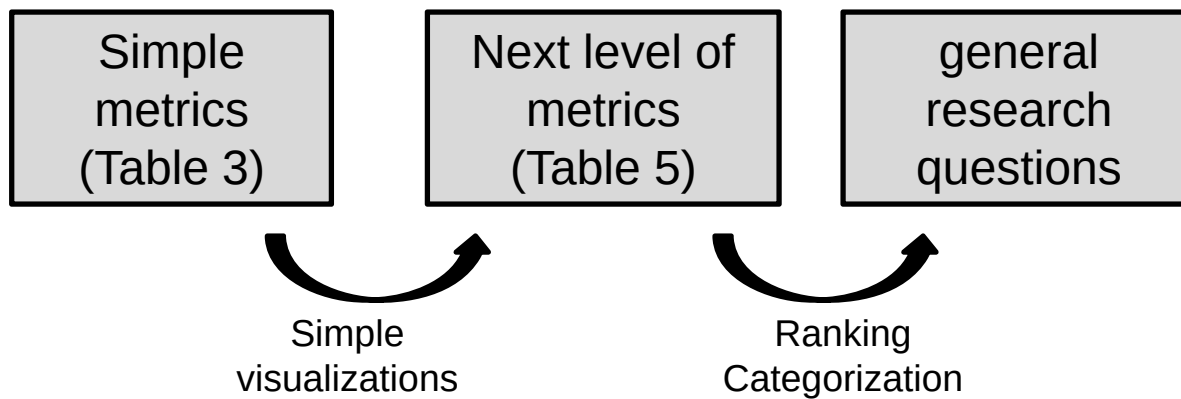
Simple
visualizations

Categories				
task load	mental workload	attention	other metrics*	performance
nr. of arrival flights	fixation frequency / duration	nr. of changes in AOIs per time unit	nr. of mouse clicks	Error messages
nr. of departure flights	heart rate measures	fixation duration on AOIs	Nr. of callsigns/ number of communications	nr. of tasks completed / not completed
nr. of task switches	subjective stress levels	standard deviation of fixation duration	nr. of words used	Time of task completion
*) includes behavioural metrics not assigned to certain user states due to lack of literature findings				

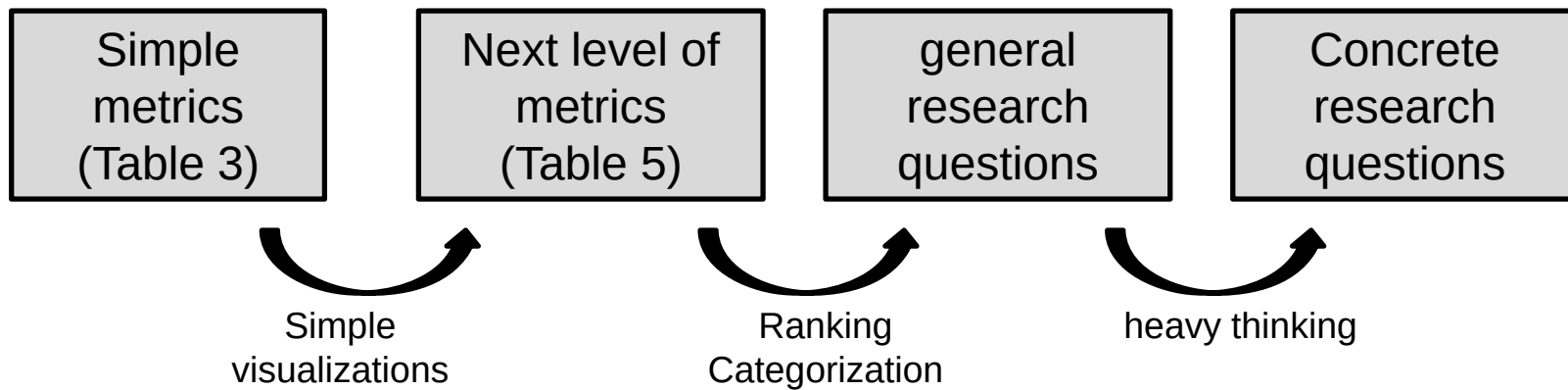
5 General Research Questions

- How to improve the user interfaces usability?
- How to detect main causes that lead to mistakes (e.g., using air traffic info, eye tracker, mouse, heart rate data, body pose)
- What are the hidden data signs that we can incorporate in an automated system to detect and predict
 - the users next actions or to predict
 - when a user is in a high workload situation or is about to make a mistake?
- What are the unknown factors that contribute to higher stress levels or to the lack of situational awareness?
- Can air traffic information be combined with sensor information to improve the detection and classification?

Approach to guide our Analysis



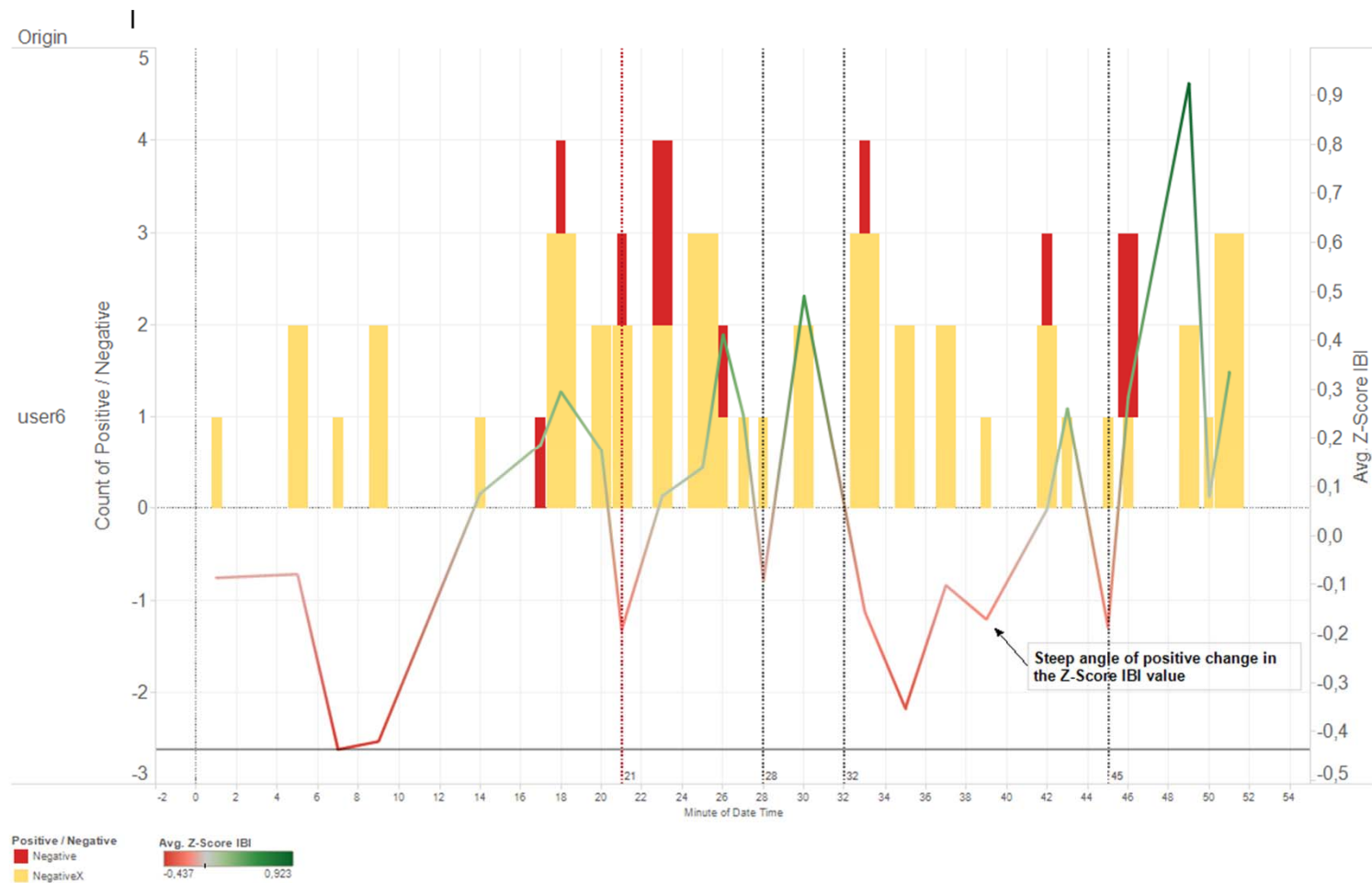
Approach to guide our analysis



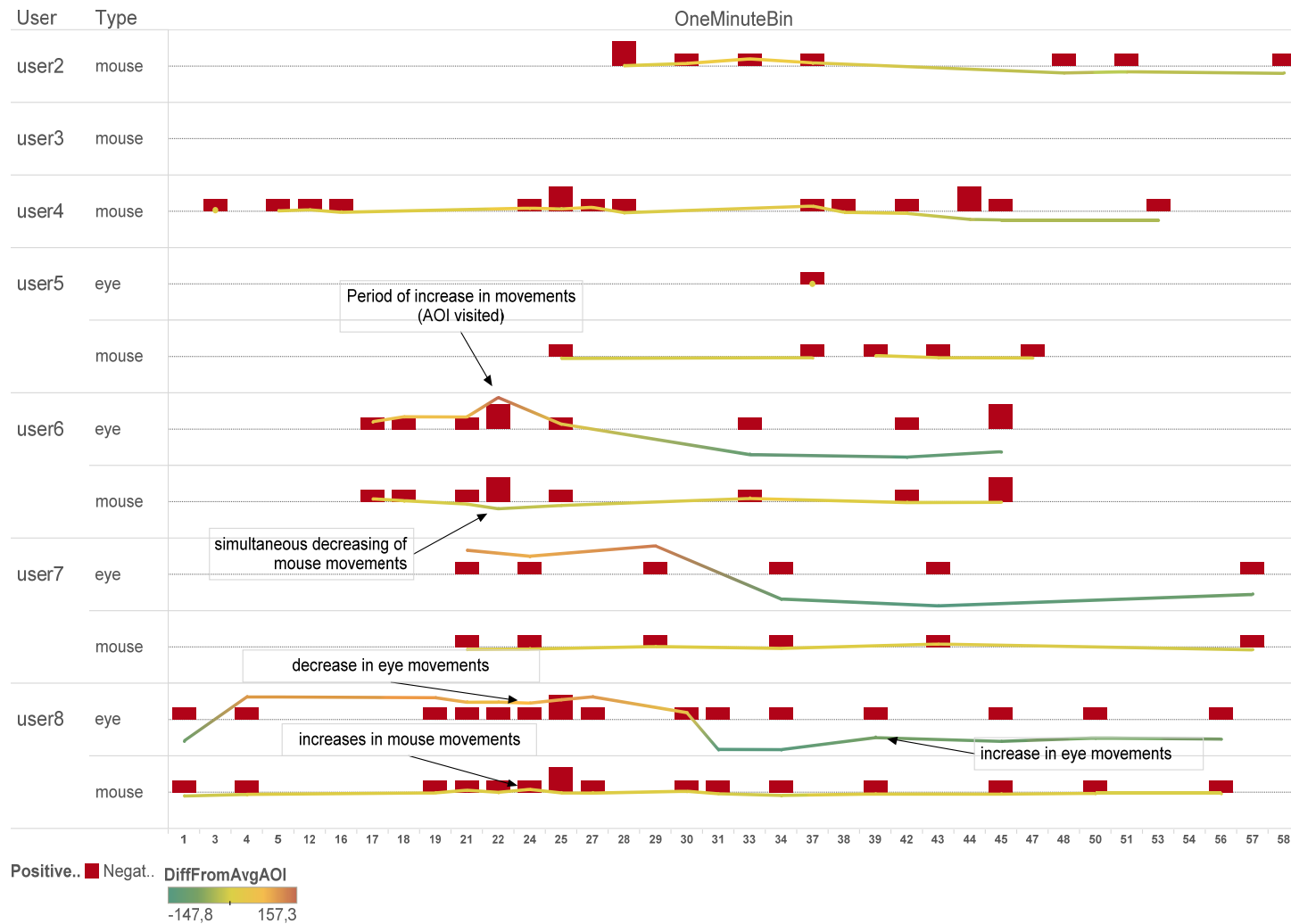
Results

Highlighting some examples of our findings

Correlation between Heart Rate Variability Data and negative observations

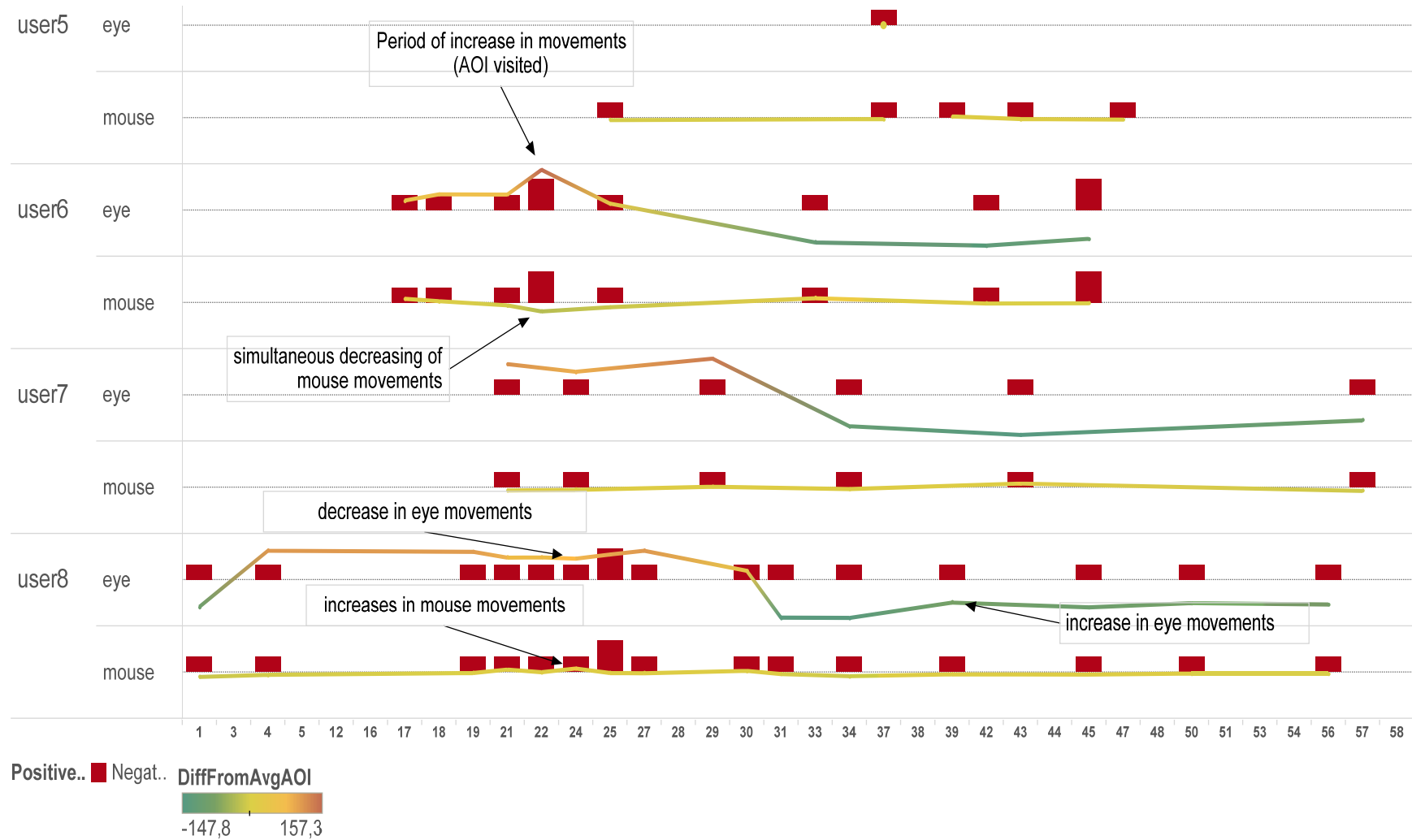


Relation between mouse and eye movements (AOI) and occurrence of errors

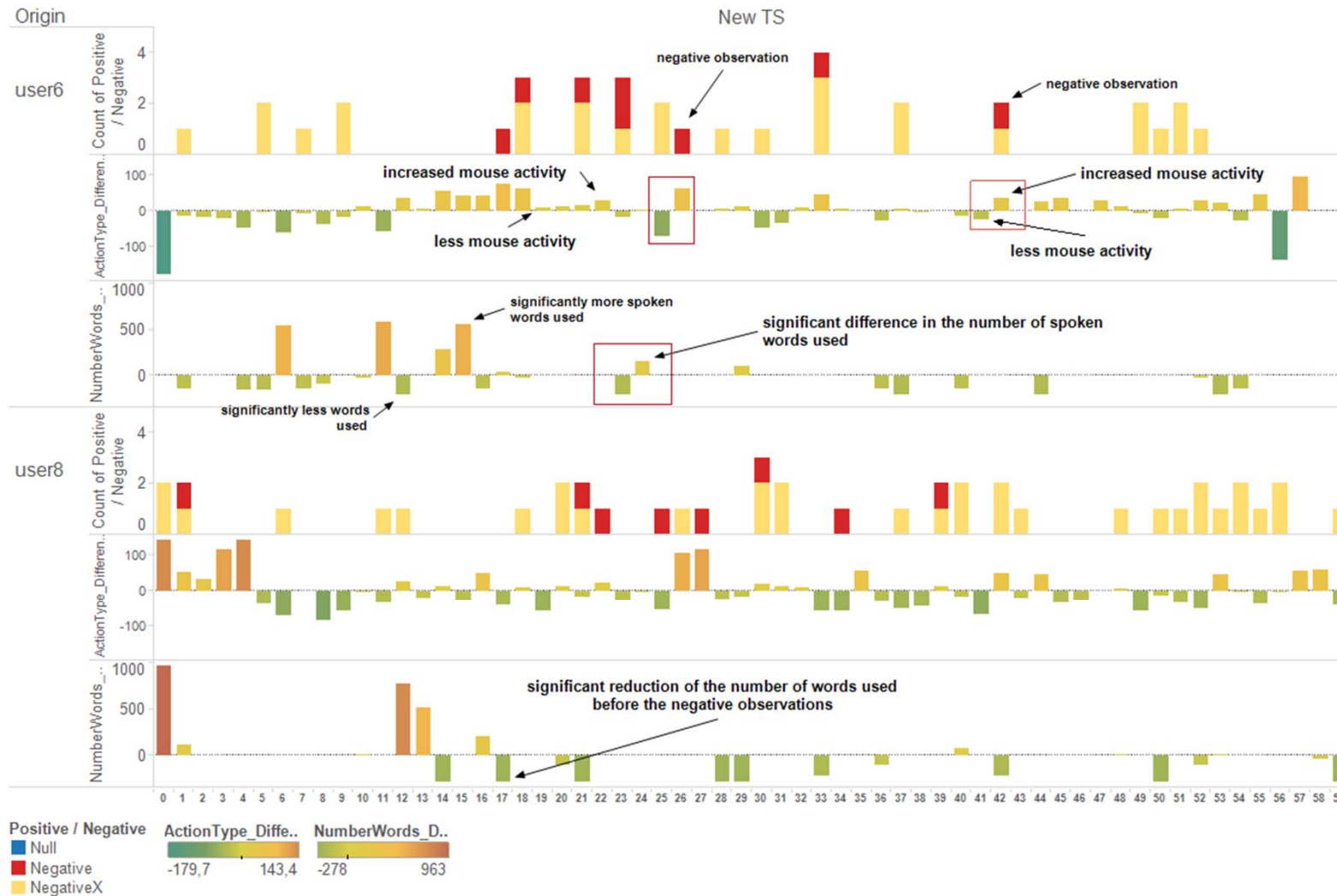


based on 09-08-30-js4_PPT_Master_IGD

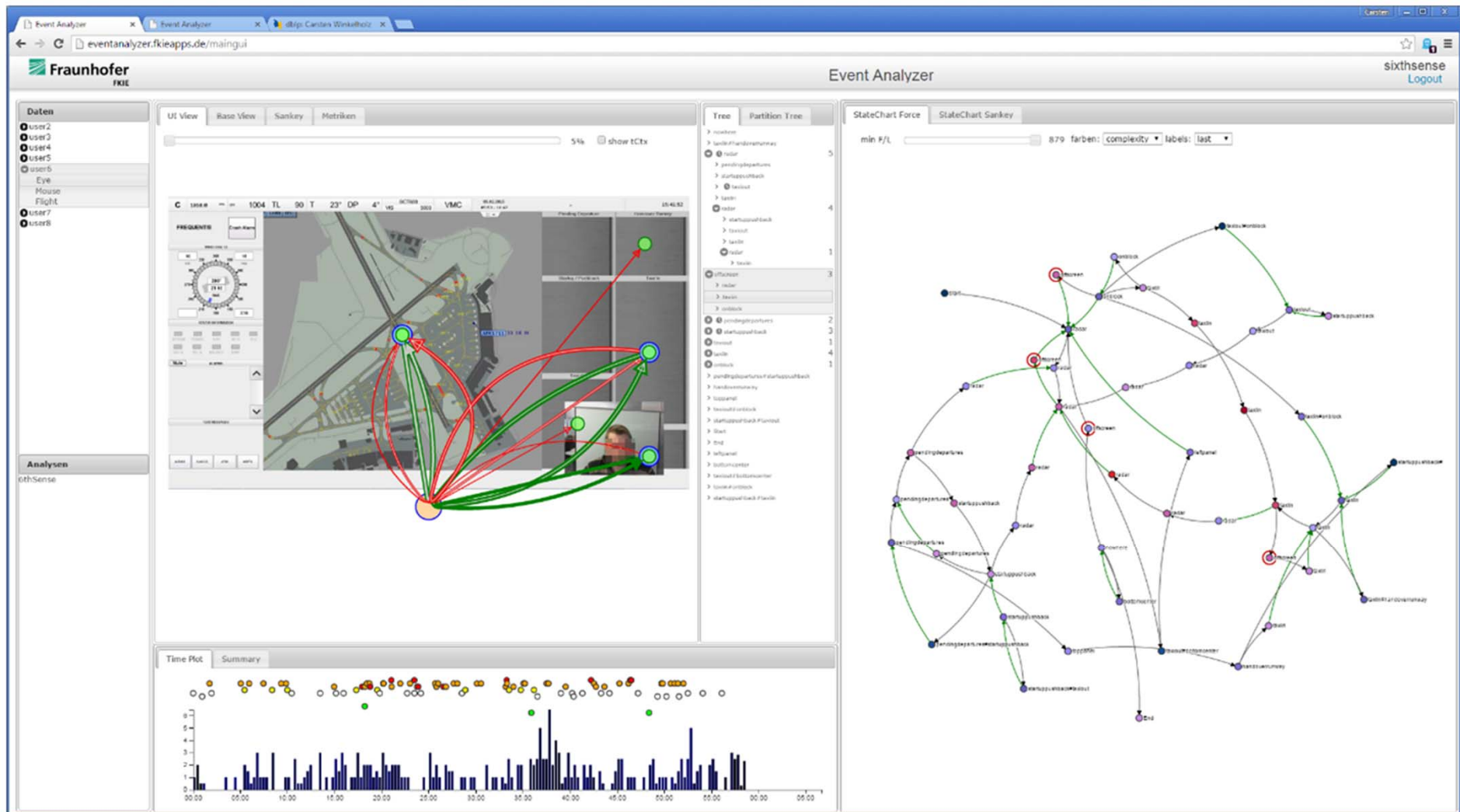
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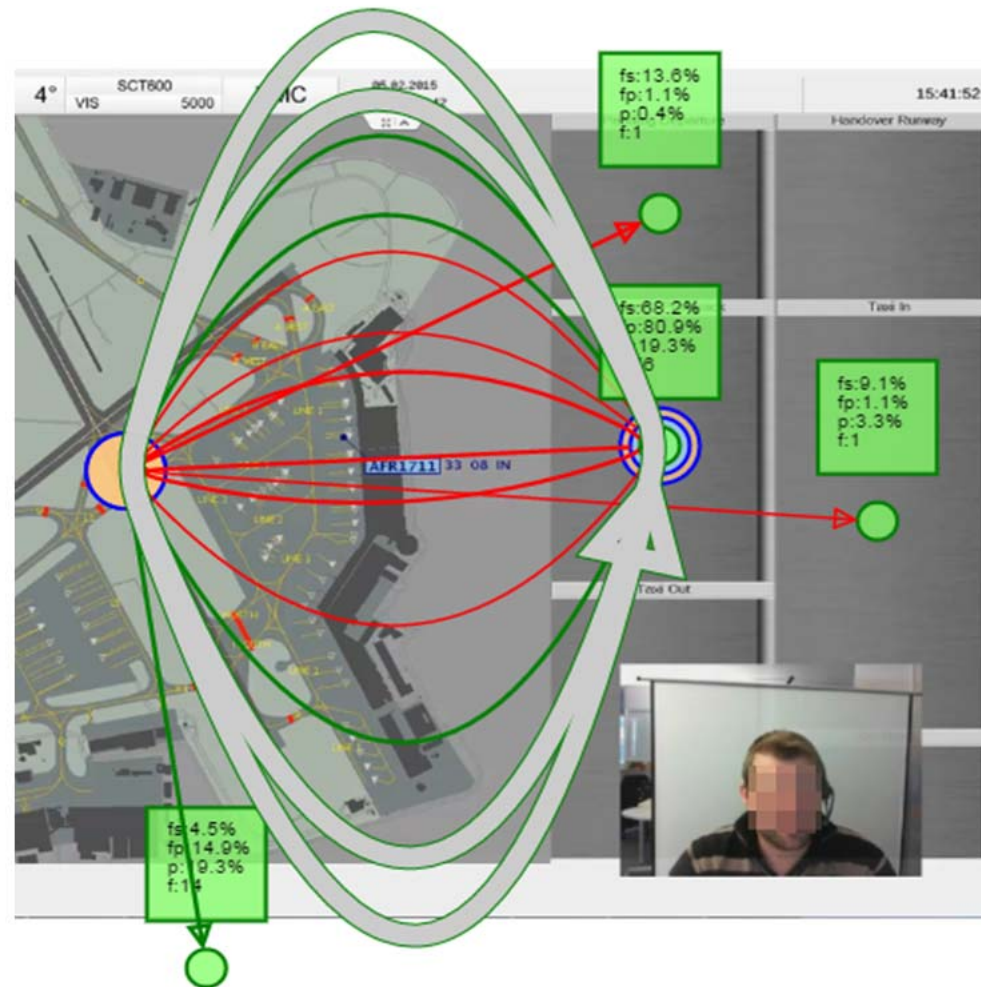
Correlation of negative observations and difference in number of words/mouse actions:



Sequential Patterns of Interaction Sequences



Sequential Patterns



Summary of Results

- Reductions in mouse movement and increases in the eye movements coincident with the occurrence of negative observations. (Figure 45)
- The HRV together with the reduction in mouse activity, the number of visual UI objects to be managed and the eye tracking AOI frequency and duration provide very good clues for anticipating moments of stress and high workload.
- direct relations between increase in the number of words used by ATCO and occurrence of negative observations (Figure 50)
- [correlation between the users head position and negative observations that indicate promising model creation for predictions.]

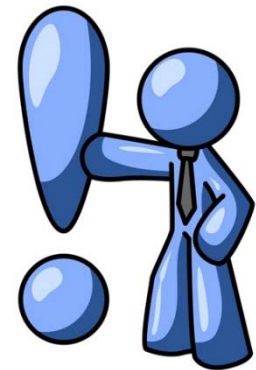
Conclusion

- Few studies about multisensoric HMIs in safety critical environment available
 - We are at the very beginning with this research!
- Our research should motivate follow up projects
 - We have indications that there are specifiable patterns for similar “situations”.
 - Therefore, it can be assumed that prediction on those patterns is possible.
- Our work proves that both hypotheses are testable – although it was beyond our means with given resources.



Lessons learnt

- Next experiments should use more sensors in multiple combinations.
 - EEG, Kinect, sophisticated Voice Recognition
- More experiments are needed with more and smaller exercises
 - ...instead of full traffic simulation.
- More reliable and distinct qualification of “good” and “bad” needed
 - E.g. through self assessment



The End

Questions?