High-fidelity human-in-the-loop simulations as one step towards remote control of regional airports

A preliminary study

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The paper reports on an experimental work environment for simulating remote control of regional airports and initial results obtained by high fidelity human-in-the-loop simulations. At the Institute of Flight Guidance of the German Aerospace Centre a concept for remote control of regional airports was developed since 2002 and a corresponding experimental testbed realized, consisting of facilities for field testing at the Braunschweig research airport and a tower simulator extension for operational remote tower (RTO) simulations with controllers. Human-in-the-loop simulations were conducted, simulating Braunschweig airport to show the operational feasibility of the new working environment. Therefore two tower controllers handled traffic scenarios using a common 200-degree tower simulator, but also using the new work environment, the RTO (Remote Tower Operation)-Console. This setting allows a direct comparison of an evaluation of the RTO-Console and the tower simulator as work environment. Augmented vision aspects were implemented in the simulation runs at the RTO-Console. Moreover, a zoom camera with an automatic tracking function integrated in the work environment for remote control was evaluated. Subjective data from questionnaires and free interviews were gathered for each simulation run. Objective eye data were recorded for the simulation runs using the RTO-Console. The main result from the questionnaires depicts the work environment of the RTO-Console to be comparable with working in a tower simulator. The eye data show that most of the time (53%) the tower controller is looking at the area of interest in the simulated far view, which is in line with former work analyses. The results of the human-in-the-loop simulation suggest the feasibility of tower operation using the RTO-Console. For the operational deployment of remote control of small airports a stepwise validation using human-in-the-loop simulations is indispensable.

Keywords - Remote Tower, Controller working position, simulation, validation, eye-tracking

I. INTRODUCTION

The concept of remote control of small airports is a great challenge with regard to the implied changes in the controllers work environment. At German regional airports air traffic control is provided by a controller team located in a tower with direct view on the airport. A concept for remote control of small airports must guarantee safe operations. One important question within this context relates to “which” information an air traffic controller needs to guarantee safe operations on the airport.

Research in the past did not focus on the work environment of tower control. According to Hein [1] research focused on radar controller positions due to the higher potential for implementing new technologies. Hagemann [2] cites that automation for tower controllers seems impossible due to the high number of unforeseeable events. He mentions for example events like runway inspections by staff of apron control, obstacles on the runway or rejected landings or takeoffs. Even though these events are not linked to the direct line of sight from the tower, it seems that it plays a major role in this context. The importance of the far view for tower control is also pointed out by Hilburn [3] and concluded from a literature review accomplished by Tavanti [4]. However the role of the far view for air traffic control at airports remains inexplicit.

It is conceivable that this lack of understanding is the reason why remote control of regional airports is not realized yet. From 2002–2004 a concept study „Virtual Tower“ was accomplished at DLR, that initialised research concerned with remote control of small airports. Within the DLR project RApTOr (Remote Airport Tower Operation research) first steps of the concept were realized [6]6, 7]. From the arguments in the last paragraph and a task analysis at Leipzig airport, supported by the project partner DFS (German Air Traffic Control), it was concluded that the far view is a crucial information source in the safety chain of air traffic control that cannot be neglected for remote control. Therefore the work environment for remote control of airports developed, involves a reconstruction of the far view by a live stream video panorama with 180° field-of-view (FOV) and an additional zoom camera. For demonstration and proof of the technical concept an experimental system was realized at research airport Braunschweig. For more details of the camera system and the configuration of the RTO-Demonstrator as working environment, see the references mentioned above.

After the demonstration of technical solutions for the live stream video panorama and the design of the RTO-Demonstrator an ongoing study is focusing on the operational aspects of the new work environment.

A. *Aerodrome control: work environment, working positions, and tasks*

The direct view on the airport is just one visual information source. Flight strips, a RADAR and a weather display are also on the controller's disposal. Beside these visual information sources, the controller is using radio especially for communication with the pilots, ground radio and a telephone. These visual and auditory information sources and interaction devices are the main instruments for air traffic controllers on a regional airport [8]. For the aerodrome control of a regional airport there is no separation between tower and approach control. Usually a tower controller and coordinator work in a team together. Their tasks are the control and surveillance of the runway, taxiways and park areas and the surveillance of the whole aerodrome. The tower controller is in contact with the pilots via radio and responsible for the safe operations on the airport, while the coordinator or assistant is more concerned with planning the arriving and departing traffic and assists the tower controller with the protocol on the flight strips. The main difference of the tower control or aerodrome control in comparison to approach or radar control is the direct view out of the window. Although the role of the outside view is still not understood, it is one element in the safety chain for air traffic control to justify safe operations on the airport.

B *Characteristics of regional airports and the consequences for air traffic control*

Small and regional airports usually lack any electronic surveillance like ground radar. Another characteristic of regional airports is the high percentage of flights operating under Visual Flight Rules (VFR) conditions. Flights under Instrumental Flight Rules (IFR) in large parts are operated by commercial airline pilots. In contrast, flights operating under VFR conditions are mainly flown by private pilots and pilot trainees. These characteristics go in line with several consequences for air traffic control at regional airports. The VFR traffic can not be foreseen like the IFR traffic, and therefore demands flexible planning. The fact that pilots of VFR traffic are in general less experienced pilots has influences on the air traffic control service. It is likely that there are more deviations from the standardized controller-pilot radio communication and there is less confidence, that the pilots follow the commands from the tower correctly. This study aims at validation of the video panorama. It is assumed that the RTO-Console is able to represent the crucial changes for the work environment provoked by the RTO-Console.

C *Information superimposition into the video panorama and automatic zoom camera tracking for controller assistance*

The replacement of the outside view by a live video as suggested for a remote control working position offers new possibilities for controller assistance. This is interesting especially for poorly technically equipped regional airports. The live video offers possibilities like image processing algorithms to automatically detect aircraft or other moving objects [9]. Some research has been performed on augmented vision, i.e. superimposition of flight information on the far view within the real tower environment [10, 11, 12, 13]. Augmentation is more easily realized within the video panorama because for the vehicle tracking case no alignment of augmenting information between distant moving vehicle and observer position is necessary [6, 7, 9]. Within the following simulation study, information superimposition with object tracking and semi-automatic zoom camera tracking will be integrated into the experimental remote tower environment.

D *Realization of an operational concept for remote control in a high fidelity simulation environment*

The realization of an operational concept for remote control of regional airports in a high-fidelity simulation environment is important for a stepwise validation. The RTO-Console with its four displays for the panorama view and an additional display for the zoom camera was therefore integrated into the tower simulation environment at DLR Braunschweig. The aim of the following study is to investigate the operational feasibility of an RTO work environment offering a videopanorama of the airport and a zoom camera to one controller team (tower controller, coordinator). In addition to that a focus is set on the examination of new possibilities of controller assistance at the remote working position. The utility of a zoom camera with a semi-automatic tracking function and the utility of information superimposition will be investigated.

As methodological approach for validation of the novel work environment, working in a common 200-degree tower simulator is compared to working with the 180° RTO-Console. In the following human-in-the-loop simulations the four different conditions were realized that are now introduced.

1) Tower simulator

In the first simulation run one controller team works in a conventionally high-fidelity tower simulator, simulating Braunschweig airport.

2) RTO-Console Baseline

This experimental condition is for the straight comparison of the tower simulator and the RTO-Console. A controller team is working at the RTO-Console.

3) RTO-Console and image processing

Compared to condition 2, image processing algorithms are realized for the detection of moving objects. Moving objects are visualized by a coloured frame. It is further possible for the tower controller to direct the zoom camera on one moving object and start the automatic tracking of that object by a touch pen.

4) RTO-Console and data fusion

It is assumed, that in the near future also regional airports are able to receive and process position data via MODE-S transponder or GPS-ADS-B. These data involve position data, but also the callsign of the aircraft. In this condition, the callsign is displayed next to the aircraft. Moreover the transponder data are used for the semi-automatic tracking function, like in condition 3.

II. METHOD

A. *Subjects*

Two tower controllers from Braunschweig tower participated in the high-fidelity simulation study. Both participants operate as tower controllers since more then 25 years and are working in Braunschweig since more then 20 years. Their mean age was 53 years. They were announced an expense allowance.

B. *Experimental Design*

A 2*3 factorial quasi-experimental design was tested with the factors weather (good visibility, bad visibility) and working position variants (tower simulation, RTO-Console baseline, RTO-Console + augmented vision). The weather condition was varied between day one and two. On day one the augmented vision aspects were realized using image processing. On day two the callsign (datafusion) was displayed. The experimental design is depicted in table 1.

	Simulation day 1 (good visibility)	**Simulation day 2 (bad visibility)**
Baseline	Tower simulator	Tower simulator
Baseline	RTO-Console (no zoom function)	RTO-Console (no zoom function)
Augmented vision	RTO-Console › image processing › zoom camera + automatic tracking	RTO-Console › datafusion (callsign) › zoom camera + automatic tracking

Table 1. Experimental design

C. *Simulation Setup*

The RTO-Demonstrator was integrated into the ATM-simulation environment at DLR in Braunschweig. For the tower simulator a 4-beamer-front-projection on a 200° spherical surface was realized, imitating the view out of the window without shrinking of seizes and proportions. The RTO-Console was equipped with a 4-beamer rear projection on 1200*1600px resolution, 30'' displays. The video on RTO-Console was brighter, had a better contrast, saturation and sharpness in comparison to the tower simulator. The simulation setup of both, the tower and RTO simulation comprises two controller working positions (tower controller, coordinator), two pseudo pilot working positions and a supervisory working position. The integration of these five working positions into the ATS with the Simulation Server, image generator and environment is depicted in figure 1.

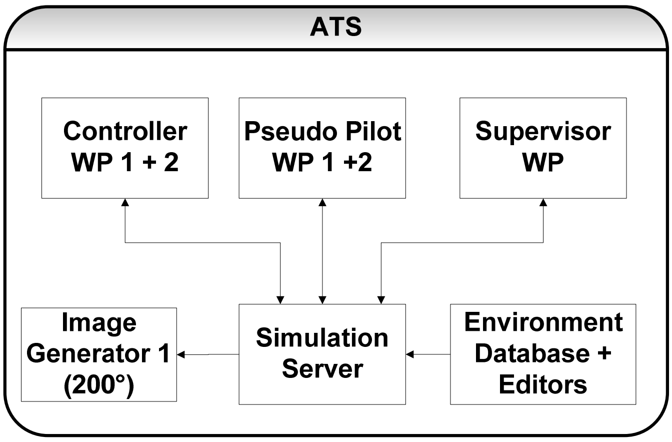

Figure 1. schematic simulation setup

D. *Working positions*

In the following the five working positions are introduced, before a description of the generated traffic scenario is given.

The two controller positions (tower controller and coordinator) are equipped with a generic RADAR application, a weather display, flight strips, radio and the far view. Within the tower simulator two RADAR applications were used, because of the large distance from the coordinator working position to the RADAR placed in front of the tower controller position.

At the RTO-Console there is an additional control display in front of the tower controller for the zoom camera, but just one RADAR right in front of the coordinator working position. The configuration of working positions are depicted in figures 2 and 3.

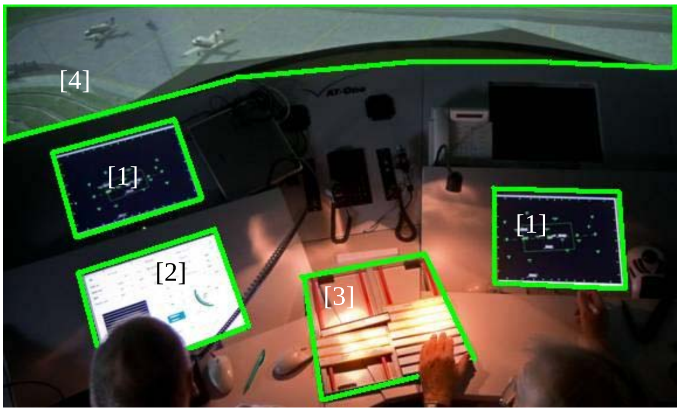

Figure 2. Design of working positions in the tower simulator compasses [1] RADAR, [2] weather display, [3] flight strips, [4] far view.

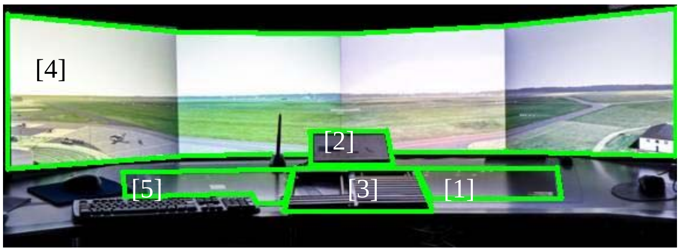

Figure 3. Design of working positions of the RTO-Console [1] RADAR, [2] weather display, [3] flight strips, [4] far view (videopanorama), [5] controldisplay (zoom camera)

At the two pseudo pilot working positions, located in a separate room, two trained pseudo pilots control the aircrafts by a commando pad and mouse clicks, according to the radio advices from the tower controller. They are responsible for heading, speed and altitude advisories and the clearances of all aircraft in the simulation.

The supervisor is responsible for the start-, freezing- and stop- commands in the simulation.

The traffic scenarios differed in actual callsigns of the aircraft, so that there was no learning effect over the different simulation runs, but all were designed with a similar demand and overall traffic mix of 60% VFR-traffic. The simulation scenarios always allowed VFR-flight operations even with weather variations.

E. *Data acquisition*

1) Questionnaires and interview

After each simulation run, both controllers had to fill out a questionnaire concerning the usability and acceptance of the whole system. Therefore questions from the EUROCONTROL SHAPE questionnaires were used, that were developed to access the influence of automation on workload, situational awareness, team work and trust [14]: Parts of the SHAPE-AIM (assessing the impact of automation on mental workload), parts of the SHAPE-SATI (system automation trust index) and parts of the SHAPE-SASHA (situational awareness for SHAPE) were used. Every item was rated on a seven-point Likert scale. Further questions from the system usability scale (SUS) were used to access subjective rating concerning the usability of the RTO-Console on a five-point Likert scale [15].

Afterwards the free interview was used, to record the feedback of the controllers concerning the RTO working environment and the novel system components (zoom camera, touch pen and tracking function).

2) Eye-tracking

During the simulation runs at the RTO-Console eye tracking data were recorded. The eye data are valuable objective data on the information acquisition of the tower controller and the coordinator. However, eye-data recording in such complex environments like the tower simulator or RTO-Console is not trivial. Hence controllers look at quite a lot different information sources and might stand up from their chairs to have a better look at specific areas on the airport. The head-mounted system iView-X from company SMI has the disadvantage that it comes in its original form in combination with a magnetic head-tracker (polhemus) for data based analyses [16]. Such head-trackers implicate about three disadvantages: They need a metal free environment, (2) a maximal distance of 80 cm between sensor (head) and receiver (polhemus), and (3) can just track the head of one person. Thus within the project RAiCe (Remote Airport Traffic Control Center) the coupling of an optical tracking system from A.R.-tracking with the iView-X-System from SMI was realized [17]. The system uses two infrared cameras, to track the head using “targets” and can overcome all three disadvantages.

F. *Data analyses*

1) Data analyses of questionnaires

Hence only items of the SHAPE questionnaires were used, that made sense in respect for evaluating the RTO-Console and new components (zoom camera, touch pen and tracking function) no standardized data analysis is possible. Here, sum scores are calculated for the items of each questionnaire. Thereby it is respected that several items are inverted in their values.

For the contrast of the different experimental conditions the sum scores of the different controller positions (tower controller, coordinator) and simulation days (one, two) are aggregated (compare table 1). According to these aggregated data the different working conditions (1) tower simulation, (2) RTO-Console Baseline and (3) RTO-Console (Augmented Vision) are compared on descriptive level. Inferential statistics are denied for the sample of two controllers.

The comments of the free interview will be summarized according to four categories: (1) design and arrangement, (2) augmented vision aspects, (3) other suggestions, (4) general comments.

The category “design and arrangement” will consider the arrangement of the instruments at the RTO-Console. Under “augmented vision aspects” all comments concerning the superimposition of information and the usability of the zoom camera will be summarized. “Other suggestions” will report controller comments in respect to the design, arrangement and augmented vision aspects and the last category “general comments” is for remaining remarks.

2) Analyses of eye-tracking data

The analysis of eye-tracking concerns the dwell times for the different information sources as an index for the visual attention distribution.

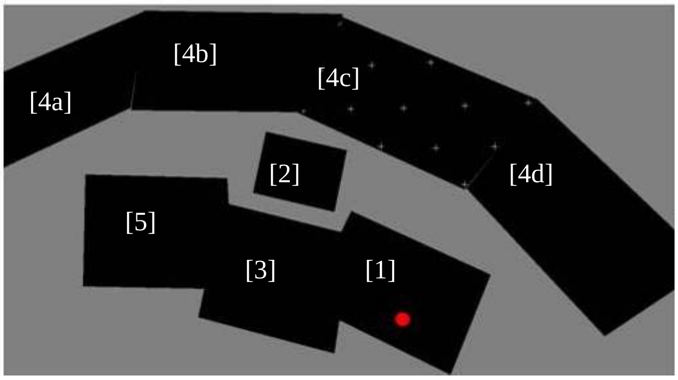

Figure 4. 3d-Modell of the information sources (planes) of the RTO-Console as basis for data driven analysis of eye-tracking data

The present analyses will focus on the differences of this index between the tower controller and the coordinator. For these data analyses it is essential to generate a 3d-model of the RTO-Console, which includes the positions of all visual information sources (planes). It can be seen in figure 4. On plane 4c there are 13 white crosses used for the calibration of the eye tracking system. All four displays of the panorama will be defined as four separate planes (4a-4d). Due to the layout of airport Braunschweig the four displays can be assorted to four different functional areas of the airport that are mainly represented on a specific plane.

- 4a) Departure - due to the runway direction 26 used in all simulation runs
- 4b) Park area – this display includes the park areas
- 4c) Runway – on this display (sometimes extended into 4b)) the touch down of aircraft takes place
- 4d) Approach- due to the runway direction 26 used in all simulation runs

Following the eye data recording based on the 3d-model, the eye-tracking analyser (EyeTA) is used. The EyeTA is a tool that was developed at the DLR Institute of Flight Guidance, to be able to analyse large eye-tracking data sets even for a large sample size. For calculation of fixations the algorithms suggested by Salvucci and Goldberg were implemented [18]. The user interface is shown in figure 5.

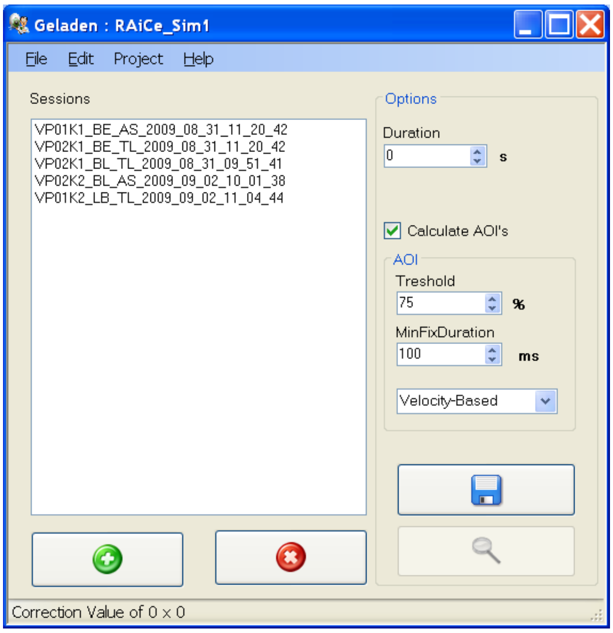

Figure 5. User interface of the eye-tracking analyzer

III. Results

The present section is subdivided into subsection 3.1 reporting the results of the questionnaires, subsection 3.2 which addresses data of the free interview, and subsection 3.3 presenting the eye-tracking results.

A. *Questionnaires*

For the AIM and SASHA questionnaires a maximal value is found for the simulation runs tower simulator, lower values are found for RTC-Console (baseline) and the least values are found for RTC-Console (with augmented vision). The aggregated sum score for the tower simulator is 123, for the RTC-Console (baseline) 121 and for the RTC-Console (with augmented vision) 103. For the SASHA the aggregated sum scores are 30, 25 and 24 for the simulation conditions tower simulator, RTO-Console (Baseline) and RTO-Console (augmented vision) respectively. Over the three conditions the data show a trend for a decrease of the mental workload and a less negative influence on the situational awareness.

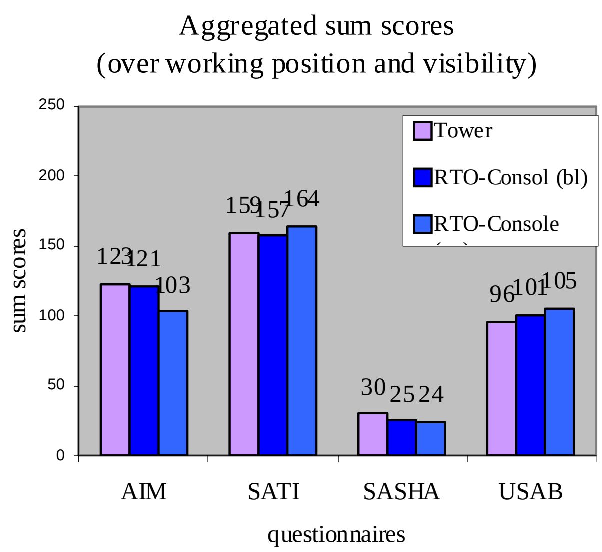

Figure 6. Sum scores of the questionnaires aggregated over working positions and visibility

For the aggregated data of the SATI questionnaire the (1) tower simulation is rated 159, the (2) RTO-Console (baseline) is rated 158 and the RTO-Console (augmented vision) is rated 164. Though the differences are very small, the RTC-Console (augmented vision) shows the highest system trust in automation index. Finally the USAB shows the smallest value for (1) the tower simulator with 96. The evaluation of the (2) RTC-Console (baseline) ended up with a value of 101. The highest value was given to the RTC-Console (augmented vision) with 105 points. The data a depicted in figure 6.

B. *Free interview*

The results of the free interview will be summarized in four predefined categories.

1) Design and arrangement

For the RTO-Console both controllers mentioned at the end of simulation day one to place the weather display in the centre of the RTO-Console. On left side, it was hardly seen by the coordinator and the tower controller complained the long distance between weather display and RADAR. For the RADAR both controllers ask for a steeper angle to facilitate the view on the RADAR from the tower position.

2) Augmented vision aspects

The augmentation of moving objects by a coloured frame was rated as unnecessary by the tower controller. He mentioned to know about all aircraft positions and that he can’t see the assistance value. In contrast the coordinator rated the frames more positive as they can help especially the coordinator to update his picture about the traffic on the airport, after longer planning tasks focusing on the RADAR and the flight strips. The superimposition of the callsign into the far view as it was realized on the second day of simulation was rated good and valuable. It helps not to confuse the callsigns when aircraft line up for take off. It was also mentioned that the callsign can be valuable, if it is placed right next to the aircraft, to narrow the field of search for arriving traffic at the horizon. The ability to use a touch pen to activate an automatic tracking of the zoom camera for arriving traffic was rated as a positive characteristic of the RTO-System. One controller mentioned that within the daily operations at a tower, the controller is using the binoculars quite often, to track arriving aircraft.

3) Other suggestions

The controller recommended activating the callsigns only for aircraft, which are in contact with the tower controller via radio. After an aircraft has reached its parking position, or an aircraft has not yet asked for taxiing the callsign is of no interest for the controller team.

4) General comments

One controller mentioned that he preferred working at the RTO-Console compared to the tower simulator. He realized that the resolution of the simulation and the brightness was much more comfortable at the RTC-Console. Even the touch-and-go manoeuvres were clearly visible at the RTC-Console. Regarding the question what the most important information sources are, it was mentioned, that for the tower controller the most relevant information source is the outside view and radio, in contrast to the coordinator who uses the RADAR and flight strips most often. These subjective rating will be compared with the objective eye data in the discussion section.

C. *Eye-tracking data*

The recording of the eye-tracking was successful for the tower controller in the simulation run RTC-Console (baseline, day1) and for both controllers in the simulation run RTC-Console (image processing, day1). On the second day only one eye-tracking system was available and therefore recording was conducted for the coordinator in the baseline condition and the tower controller in the datafusion condition. An overview of the eye data sets is given in table 3.

Simulation runs with recording of eye data	**tower controller**	**coordinator**
day1: RTO-Console (baseline)	successful recording	recording not successful
day1: RTO-Console (image processing)	successful recording	successful recording
day2: RTO-Console (baseline)	no recording	successful recording
day2: RTO-Console (datafusion, callsign)	successful recording	no recording

Table 3. Overview about present eye data

As a first index the fixation and macrofixations were calculated for each simulation run. It arises, that there are comparable numbers of fixations and macrofixations for all simulation runs with successful data recording. The minimal number of fixation appears for the tower controller in the RTO-Console baseline condition with 3035 fixations. Most fixations are found for the tower controller in the RTO-Consol datafusion condition, displaying the callsign. The macrofixation also vary within a narrow range between 605 and 705. The relative frequencies of fixational dwell times for single AOI's as well as AOI's aggregated for single controllers exhibit clustered Poisson statistics, i.e. somewhat steeper-than-exponential probability density functions.

The five data sets (coordinator (n=2), tower controller (n=3)) are used to compare the mean percental dwell times of the coordinator and the tower controller on the different information sources. For a graphical representation of these data regard figure 7. While the tower controller directs his visual attention to the video panorama for 53%, the coordinator spends just 34 % on the outside view.

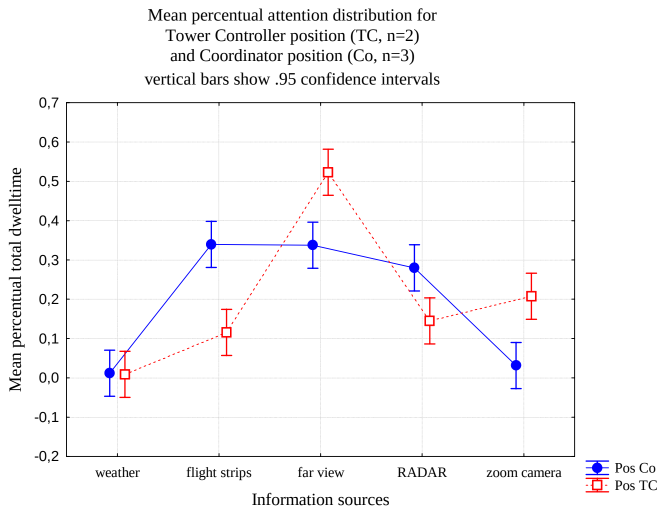

Figure 7. Mean percentual distribution of the visual attention on the different information sources, according to the working positions.

He is fixating the flight strips 34% of the time and the RADAR 28% of the time. The tower controller is just looking at the flight strips 13% and on the RADAR 17% of the time.

Further it is calculated which areas of the far view are of interest in respect to the two working positions. The data show that the tower controller and coordinator both spend 21% of the time looking in the approach area. The tower controller spends 24% looking at the departure area, while the coordinator is looking into this area only 8% of the time. Both controller positions spend about 5% with looking on the runway and 7% and 5% respectively on the Apron area. The results are summarized in figure 8.

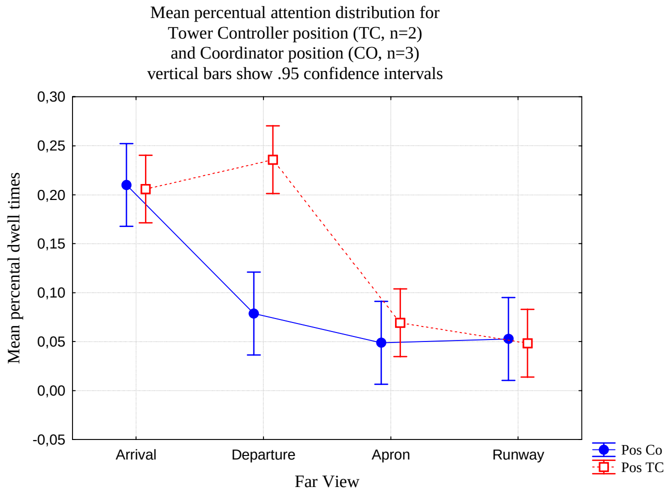

Figure 8. Mean percental duration of the visual attention on the different areas on the airport, according to the working positions

IV. Discussion

A. *Subjective Evaluation of the RTO-Console (questionnaire)*

The subjective rating of the controllers gave evidence that working at the experimental RTO-Console there is no negative effect on the situational awareness (SASHA) no increase of workload (AIM), no negative effect on the system trust in automation index (SATI) and no decrease in ratings about the system usability (SUS).

The comparison of the results working in the tower simulator with working at the RTO-Consol for validation is accepted insofar, as human-in-the-loop simulations in a tower simulator are an accepted method to draw conclusions about the working conditions in a real tower.

To the knowledge of the authors, this is the first simulation study for the validation of an RTO work environment. Even though the results from the questionnaire have just descriptive character (n=2) the ratings concerning situation awareness, work load and usability are important to ensure, that the changes of the design of the work environment (RTO-Console) have no negative effect on the controllers' operation to do air traffic control service.

B. *Free interview*

The feedback concerning the system arrangement was positive and the minor changes of the weather display and RADAR do not need further discussions.

The feedback concerning augmented vision aspects was in general positive. Superimposition by frames that depict detected moving objects, were seen as helpful for the coordinator. For superimposition of the callsigns the controllers mentioned two concrete positive aspects, reducing confusion of callsigns and narrowing the search of arriving traffic. In general the superimposition of information is motivated by the surveillance task of the tower controller. According to Hilburn head-down times are the major contributors to the risk of missing critical events [3]. In his study head-down time defines the time, when the controller is not looking out of the tower window. It is the task of future research to learn, if minimizing head-down times by superimposition will in fact minimize the detection of critical events.

The use of a zoom camera for automatic tracking of landing and starting aircraft was also rated positive and easy to use. The feedback pointed out two aspects for the question, which information is needed by the tower controller: He is looking for "gear down" of arriving traffic and if an arriving aircraft definitely left the runway after touch down. This information is checked visually, according to today's operation. A display, representing a zoom video tracking an arriving and landing aircraft, can be a valuable assistance tool for the controller to get this information.

Other suggestions of the controllers pointed out, that a classification of information into relevant and irrelevant information is important for augmented vision aspects. If a tower controller's work environment will include a video panorama the superimposition of information will be easy. However in the simulation runs the controllers were not interested in callsigns not in contact via radio with the controller. Research must set more effort to identify the task relevant information, not to display too much information in the video panorama.

The final feedback one controller mentioned the difference that the tower simulator has a worse resolution and less brightness compared to the RTO-Console. It is conceivable that this fact is an explanation for the better ratings on the SUS in the RTO conditions.

C. *Objective Eye Data*

The reduced eye data set does not allow a comparison of working at the RTO-Console and working in the tower simulator. The analyses of the eye gaze position within the new working environment in this study focuses on the visual attention distribution on displays and instruments and on a comparison of both controller.

The eye data show, that the tower controller spends most visual attention on the panorama, which resembles the view out of the window. These values are in line with reported results in the literature [19]. What is not found in the literature is the comparison of the visual attention contrasting the tower controller and the coordinator working positions. The objective eye data show that the most used information source is the view on the panorama video. The coordinator is looking most of the time on the RADAR and on the video panorama followed by the flight strips. The difference between the working positions can be explained with the different tasks the controllers have to conduct. It is interesting to note that they accord with the comments of the controllers', that the most important information source for the tower controller working position is the view out of the window and radio, while for the coordinator the RADAR and the flight strips are much more of interest.

A more detailed analysis of the far view shows a big difference between the two controller positions on the departure display. On this display it is possible to see, if a landing aircraft left the runway and if departure traffic is taking the flight routes commanded by the controller. The data support that this information must be confirmed by the tower controller. It is not the task of the coordinator to verify this information by looking out of the window.

V. SUMMARY

Overall, working at the RTO-Console and the traffic scenarios were seen as realistic. The results of the questionnaires show, that working in the simulation condition RTO-Console with augmented vision got the most positive ratings. The results of the SASHA questionnaire show the lowest aggregated sum scores, meaning that there is no negative effect on the situational awareness. The responses of the AIM also show the lowest values indicating the lowest workload compared to the tower simulator and RTO-Console (baseline).

The system trust in automation index (SATI) and the sum scores of the system usability scale reveal the highest scores for condition RTO-Console with augmented vision. These values assigning the RTO-Console the best scores for trust and usability are no large effects, but they represent a convincing result. They implicate, that the RTO-Console is not showing any deficits, compared to the tower simulator, which in this setting represents the common work environment.

From the free interview one can conclude that the design of the RTO-Console as it was realized enables a controller team to handle the traffic of a regional airport successfully. The comments about the weather display and the angle of the RADAR display are not critical for the general operational concept, but aim at optimization of the instrument arrangement at the RTO-Console.

The superimposition of information was accepted by the controllers and the zoom camera was appreciated as replacement of binoculars. It is useful to verify important information e.g. that a landing aircraft left the runway.

The eye data indicate which information is important for the controllers, and how long he is looking on different information sources. This objective method is valuable, especially for a better understanding of the role of the far view. The data indicate which information is acquired while controllers fulfill their air traffic control service.

VI. OUTLOOK

This paper introduced a preliminary study with a sample size of 2 controllers of airport Braunschweig. The sample size will be enlarged so that the full study will include data of 12 tower controllers. This will allow to calculate inferential statistics and to control for order effects and interpersonal differences. Ongoing work addresses application of advanced statistical analysis to eye movement time series of fixational dwell times for discriminating between deterministic and stochastic contributions.

ACKNOWLEDGMENT

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