Head Up Only – A design concept to enable multiple remote tower operations

Anne Papenfuss, Maik Friedrich
Institut für Flugführung, Deutsches Zentrum für Luft- und Raumfahrt
Lilienthalplatz 7, 38108 Braunschweig
anne.papenfuss@dlr.de, maik.friedrich@dlr.de

1. Motivation

Multiple remote tower control aims at enabling one air traffic controller (ATCO) to control simultaneous traffic at two airports at the same time. This concept has the advantage that workforce of the ATCOs can be utilized in an optimized way. Nevertheless, it raises the questions how the workplace should be designed in order to allow the ATCO to handle as much traffic as possible in a safe and efficient manner. One important parameter is the visual attention of the ATCO. Monitoring is the main task of tower ATCOs and is the mechanism by which ATCOs detect deviations between the preplanned and the real traffic situation [1]. As a rule of thumb, air traffic controllers are trained to "look outside" as often as possible, also called working "head-up". Especially, it is a normative behavior that the controller should monitor an aircraft during the take-off and landing phase in order to detect any hazardous events as early as possible, e.g. a burning engine. In contrast to this rule, the so-called "head-down" times [2] of air traffic controllers increased already over the past years as new information sources were presented to the ATCOs by adding displays to their working positons. So it is of interest; whether ATCOs are able conduct their monitoring task in a multiple remote tower environment where the number of sources with visual information is further increased. Specifically, the ATCOs should be able to monitor take-off and landings as good as compared to working on a single airport.

2. Method

Within the framework of SESAR 6.8.4[1], Deutsche Flugsicherung (DFS) and German Aerospace Center (DLR) jointly conducted an initial study of the influence of multiple remote tower control on human performance, capacity and safety. Sixteen ATCOs from DFS participated in the study. All of them had a valid ATCO license and were between 22 to 54 years old.

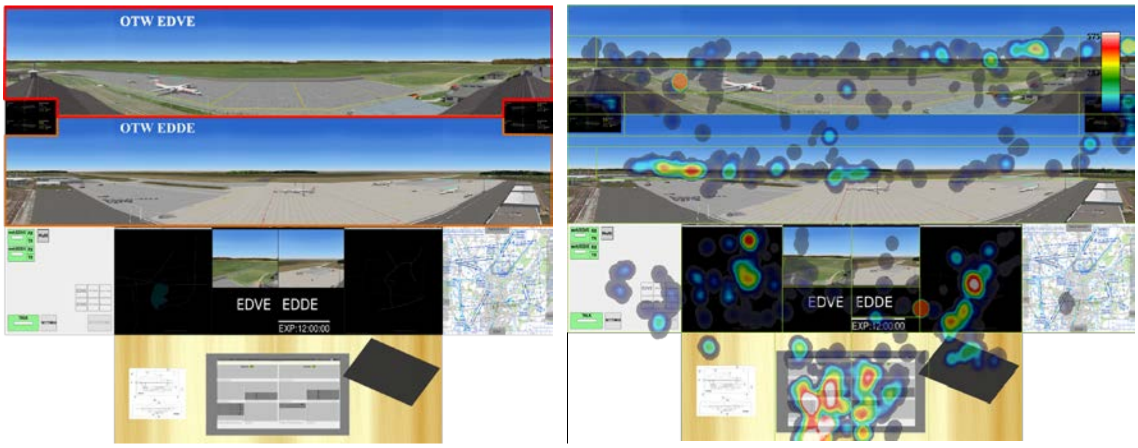

Fig. 1.: Schematic representation of the multiple remote tower work environment (left) and as one example, the heatmap visualization of the fixations of one participant during take-off and landing events. Blue color indicates little, reddish color much visual attention (right).

[1] ABOUT SESAR & SESAR JU: As the technological pillar of the Single European Sky initiative, SESAR aims to modernise and harmonise air traffic management in Europe. The SESAR Joint Undertaking (SESAR JU) was established in 2007 as a public-private partnership to support this endeavour. It does so by pooling the knowledge and resources of the entire ATM community in order to define, research, develop and validate innovative technological and operational solutions. The SESAR JU is also responsible for the execution of the European ATM Master Plan. Founded by the European Union and Eurocontrol, the SESAR JU has 19 members, who together with their partners and affiliate associations will represent over 100 companies working in Europe and beyond. The SESAR JU also works closely with staff associations, regulators, airport operators and the scientific community. Find out more: www.sesarju.eu

The study was conducted using a high-fidelity simulator setup, simulating a 180° degree panoramic outside tower view (OTW, cf. [3]) of Braunschweig (EDVE) and Erfurt (EDDE) airport. Three different experimental conditions were realized in a within-subject experimental design, which randomized the sequence in order to control for learning effects. An experimental multiple remote tower set-up was used for a multiple baseline and a multiple advanced condition. In the multiple baseline condition, the OTW of EDVE was arranged as a row of displays above the OTW of EDDE. Furthermore, approach radar and a pan-tilt zoom (PTZ) camera for each airport, electronic flight strips and a coupled radio frequency were available. Weather data were integrated into the according displays of the OTW (cf. Figure 1 left). In the multiple advanced condition, the additional features aircraft label augmentation in the OTW and automatic PTZ tracking were incorporated. For the third experimental condition (single baseline), an additional experimental single remote tower set-up was used, with the same information sources but OTW and instruments only for airport EDVE. In all three experimental conditions, ATCOs handled the same high amount of traffic (six moving aircraft at a time for a one hour scenario), including simultaneous take-off and landings. Workload and situational awareness data, observation, performance data, as well as eye gaze data was gathered during the runs.

3. Results

This paper focusses on visual attention of ATCOs during take-off and touch-down events of aircraft. An event-based eye-data analysis was conducted to determine the monitoring performance, using DLRs analysis software EyeTrackingAnalyser [4]. The analysis is based on the assumption that a touchdown or take-off is monitored, in case the ATCO spent at least one fixation on the OTW of the relevant airport within a 30 second time interval around the event. Figure 1 right shows as an example the heatmap visualization of all fixations during these intervals for one participant. Within the one hour traffic scenarios, there were on average 21 take-off and landing events. In all conditions, some events were not monitored by the ATCOs, but with a different rate. In the single baseline condition on average 98 %, in multiple baseline 92% and in multiple advanced 89% of all events were monitored. A repeated measurement ANOVA with the factor condition (single baseline, multiple baseline, multiple advanced) revealed a significant, and rather large effect of the working condition on the monitoring performance $F(2,24)=8,77$; $p=.001$; $\eta^2 = 0.42$. The post-hoc analysis showed that in both multiple conditions significantly less events were monitored compared to the single baseline. There was no significant difference in the monitoring performance between the multiple baseline and advanced condition.

The results of the simulator study were discussed afterwards with ATCOs in order to clarify the operational impact of the empirical results. During these workshops, ATCOs stated that within the single baseline condition ATCOs' visual attention remains longer on the RWY due to the fact that this RWY is also the bottleneck at the airport. The potential for a conflict was higher in the single remote condition as all traffic had to pass that single runway. In the multiple environment, the traffic is distributed on two runways thus reducing the potential for a conflict. Additionally, there was always another task to do at the other airport so it seemed less likely that ATCOs' remain their visual attention on the RWY after a touchdown or take-off event.

4. Discussion

Head-up and head-down times are important to consider in the design of a multiple tower environment. As the empirical data of the monitoring performance show, ATCOs could monitor significantly less take-off and landing events during a simulated high traffic load scenario whilst working multiple. Working two independent airports at the same time was a completely new situation for the ATCOs. The ATCOs did not have good heuristics to schedule their tasks and visual attention in an optimal manner whilst controlling high traffic numbers at two airports at the same time. Even though training might mitigate this effect, it also seems promising; especially during a transition phase, to provide assistance to the ATCOs, where to direct the visual attention to. Two approaches seem promising, to support ATCOs in this task. The first aims at presenting as many information as possible “head up” to the controller, so that s/he does not need to switch between working head-up and head down. Initial indications which information could be augmented were already given in [5].

The second approach aims at guiding the attention of the ATCOs to relevant areas. Therefore, the eye gaze position of ATCOs needs to be captured and evaluated in real-time [6]. Additionally, the traffic situation and system state is evaluated (e.g. by analyzing the input in the strip marking system or by speech recognition). A normative model predicts the areas of interest; the ATCO should pay attention to in certain systems states. The normative behavior is compared with the actual behavior. In case of a deviation, a visual or acoustic indication reminds the ATCO of the situation and that s/he should focus his attention on the runway. Further research thus should focus in evaluating the benefit of these assistance tools, in order to go the next steps towards multiple remote tower operations.

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Anne Papenfuß works within the Human Factors branch of the institute of flight guidance at the German Aerospace Center, DLR. She is exploring concepts for improving cooperation in operational environments through optimizing the information flow. Her research interest is in the study of team interaction and team situation awareness. She was planning and executing a couple of real-time high fidelity simulations, for instance in the research area of remote tower in order to develop and test operational requirements for remote tower centre control with a special focus on workload management and team work organization.

Maik Friedrich works within the Human Factors branch of the institute of flight guidance at the German Aerospace Center, DLR. He is developing concepts and methods for improving analyzing eye movement data in operational environments. This information is used to optimize the information flow. His research focus is in the study of remote tower operations and assistants systems to support air traffic controllers. He was planning and executing real-time high fidelity simulations studies following the E-OCVM, for instance in the research area of remote tower in order to develop technical requirements with a special focus on the information gathering process.