Remote Tower Centers, where Air Traffic Services are provided independently of local airport control towers, promise novel opportunities like tailored staffing concepts or more efficient work organization. In a joint approach the German Aerospace Center (DLR) and the German Air Navigation Service Provider Deutsche Flugsicherung GmbH (DFS) evaluated the concept for Multiple Remote Tower Control (RTC) in a realtime simulation exercise, addressing human factor relevant aspects such as workload, situation awareness, visual attention and acceptance.

Within this paper we focus on eye-data analysis. 16 air traffic controllers from DFS participated in the high-fidelity human-in-the-loop simulation study for multiple remote tower. Different eye-data metrics are discussed, that can characterize the visual attention of tower controllers in this new work environment.

Keywords Remote Tower Operations, Validation, Eye-tracking, ATCO performance, monitoring behaviour,

I. INTRODUCTION

Multiple remote control is a concept for a more cost efficient provision of air traffic services to airports with little traffic. Basically, one controller should be enabled by an appropriate work place to simultaneously control traffic at more than one airport at the same time. The concept of multiple remote tower control is mainly motivated by economic reasons. To provide staff and infrastructure for those small airports is very cost intensive [1].

Air traffic controllers are highly qualified people, recruited and trained to provide air traffic control for large airports with densely packed air traffic. However, also these airports with little air traffic exist, where air traffic control services must be provided for only a few aircraft movements a day. During periods with low traffic volume those towers are often manned by a single controller. While a lot of research addresses the problem of controllers’ high workload situations, in which their visual attention is overstressed, it is seldom discussed that controllers at single manned towers are rather faced with the problem to stay focused for only a few aircraft movements a day. In these towers, the visual attention capacity is not the major problem, but rather vigilance and monotony due to low traffic numbers.

Though, the concept for multiple remote tower also bares the potential to organize air traffic control in a different way, in order to eliminate single manned towers and to increase job satisfaction. But how many small airports can be assigned to a single controller? Although controllers are skilled in multitasking, their monitoring capacity is limited by the visual system and therefore by a limited visual attention capacity.

A. Multiple Remote Tower Control

The first validation exercise researching into Multiple Remote Tower control was realized within the DLR-project RAIce (Remote Air Traffic Control Center) [2]. Three different work organizations were considered when two airports are controlled from a remote tower center. Within that study three conditions of work organization were realized. First, a team of two controllers (Tower Controller and Coordinator) provided air traffic control to both airports. In a second condition, one single controller provided air traffic control to both airports. In addition, a baseline condition was realized, in which each controller was responsible for one of the two airports. A major result of this study was that workload increased compared to the baseline condition (different traffic load), however it was also found that augmented vision aspects can reduce controllers workload, under high traffic conditions for the (1) team and (2) single controller condition, but not for the (3) baseline condition. The results were further discussed with respect to cognitive redundancy and the potential benefit of a four-eye principle within the team condition.

Within the German aeronautical research program (LuFo-IV) the project VICTOR (Virtual Control Tower Research Studies) led by DFS researched into the concept that three airports are remotely controlled from a remote tower center [1]. The concept included a new master controller working position, who was responsible for ATC at several airports, during time periods with low traffic volume.

Within SESAR, research on Multiple Remote Tower is addressed within the operational focus area 6.3.1 Remote Tower e.g. [3]. There are ongoing validation activities by LFV & SAAB as well as by DLR & DFS.

B. Visual attention of tower controllers

From the literature it can be found that the work of tower controllers is more bottom-up (data driven) in comparison to enroute or approach controllers which can be described as rather top-down [4]. Therefore, tower controllers’ visual monitoring of the airport and its surrounding control zone can be seen as a critical subtask for performing their control task successfully. Further cognitive subtasks of controller, which are closely related to that monitoring task, are updating the mental picture, searching conflicts, general information processing and switching attention. In general, the monitoring of the controller can be defined as sufficient in case potential conflicts and deviations of the traffic are detected as early as possible. Therefore, a generic rule of thumb for the tower controller workplace is that controllers should look out of the tower (referred to as outside view) as often and as much as possible.

Tower controllers cannot always anticipate future situations and ensure that there will be no conflict for the next 5 minutes.
Therefore, they must monitor whether the processes on the airport are in line with their clearances. Those clearances often bare the risk for conflicts, e.g. if they allow a pilot to taxi to holding point RWY 28, there is the potential that the AC does not hold short of RWY 28. In this situation, tower controllers often must react within seconds in order to ensure safe operations. It can be therefore said that tower controllers’ visual monitoring is guided by direct or indirect triggers that indicate the potential for a critical situation. A list of such triggers has been provided by Moehlenbrink et al. [5].

An overview of eye movements measures can be found by Wickens & McCarley [6]. Beside the definition of fixation, saccade and dwell times, they introduce the concept of area of interest (AOI) which stands for an area within which all individual fixations are considered by the researcher as functionally equivalent. Tower controllers’ visual attention is often analyzed using pre-defined AOs such as out-of-the-tower view, radar, flight strips etc. Aggregated data for number of fixation, or total dwell time for a whole simulation run are often reported [7]-[8]. Those aggregated measures are used to discuss e.g. tower controllers head down times (time looking at instruments). This metric is seen critical, because, if controllers look too much on their instruments, they might miss critical events that are only detectable by the out-of-the-tower view. Although, these aggregated measures are helpful to report how much attention tower controllers spend on different AOs, these aggregated measures are not very helpful to establish a relationship between controllers visual attention and their monitoring task of certain events. Therefore, it has been suggested to use event-related data analysis metrics, to describe controllers’ visual attention on task relevant AOs [5]. Within that paper it was analyzed how often tower controllers monitored TakeOffs and Landings for arriving and departing air traffic.

In another research paper on tower control it has been addressed that no empirical research is needed to conclude that monitoring four displays for conflicts is less critical than monitoring eight displays for safety critical events [9], compare [10]. To evaluate whether one controller can control two airports it is therefore of interest, whether controllers can develop efficient attention allocation strategies that allow for monitoring of two airports in a safe manner. The mean first passage time, another eye-data metric suggested by Wickens could be used to quantify, how long an ATCO didn’t look at the other airport, when he was responsible for two airports at a time [6].

C. Functional representation of the work environment

In order to analyze, whether there are major differences in controllers overt visual attention, if they control the same amount of traffic at one airport or at two airports, it is of interest to structure the work environment into functional units: Instead of distinguishing the two airports, within this study we will only consider, if the controller was looking at flight strips, radar, outside view (panorama), radio instrument or weather data. We will not be interested whether these instruments belong to one airport or the other.

D. Research question

Within this paper, it will be discussed in which way eye-data metrics can provide valuable insight how controllers visual attention is affected, when s/he is not only responsible for one airport, but for two airports. For the eye-data analysis we are mostly interested in identifying characteristic differences for different working conditions:

A) When a single controller works two airports in the condition multiple baseline

B) When a single controller works two airports in the condition multiple advanced (automatic tracking & callsigns)

C) When a single controller works one airport (baseline)

We will look at aggregated metrics like fixation duration, dwell times, but we will also introduce moving average time windows (MAW), which have been suggested by Anders (2001) to analyze visual attention over time [11]. We suggest to use the MAW to plot controllers maximum visual attention for a certain time interval and to identify characteristic behavior of tower controllers. It will be discussed in what way the metric of controllers’ maximum visual attention can be used to characterize controllers’ visual monitoring behavior, working multiple remote tower.

II. METHOD

A high-fidelity human-in-the-loop simulation was conducted in the TowerLab of the Institute of Flight Guidance, DLR in Braunschweig.

A. Sample.

Sixteen ATCOs from the DFS participated in the study, three of them were female. All of them had a valid ATCO license and they were between 22 to 54 years old (mean = 32, sd = 11).

B. Simulation environment

The study was conducted using a high-fidelity simulator setup, simulating a 180° degree tower view of Braunschweig (EDVE) and Erfurt (EDDE) airport. The different experimental conditions were realized by two different set-ups, a single remote tower work environment and a multiple remote tower work environment. The latter included an approach radar and a pan-tilt zoom camera for each airport, electronic flight strips (left side EDDE, right side EDVE) and a coupled radio frequency. Weather data were integrated into the displays of the outside view. For the single remote tower set-up (baseline condition), was comparable but with instruments only for one airport. Within the multiple advanced conditions, it was simulated that ATCOs could use automatic tracking of aircraft and labels were overlaid in the outside view.

C. Traffic Scenarios

From an operation perspective, the requirement for the traffic scenario was 6 A/C at-a-time for the one hour simulation scenarios. For the multiple remote work environment, two different scenarios were realized, varying the traffic distribution. In one scenario traffic was equally distributed among both airports (3:3) in the other scenario, there were 5 movements in EDVE and only one or two movements at EDDE. The scenarios for the different conditions were comparable in traffic load, but different callsigns were realized. The traffic scenarios varied in positioning and timing of arriving and departing aircraft. Each controller completed three scenarios (baseline, multiple, multiple advanced). Half of the sample was assigned to the 5:1 traffic distribution, the other half to the 3:3 traffic distribution.
D. Experimental Setup

A schematic representation of the multiple remote tower work environment is depicted in Figure 1 and the corresponding 3-D environment for the eye data recording in Figure 2. The top row represents the panorama view of Braunschweig airport (5 screens, planes 2-6). The second row depicts Erfurt airport (5 screens, planes 7-11). The approach radar for Erfurt and Braunschweig are included in plane 12. The bottom row depicts the radio touch input interface for Braunschweig and Erfurt (plane 14). On the right, the user interface for the zoom cameras was placed (plane 15). Plane 13 includes the electronic flight strip bay and maps.

E. Experimental Design

A 3*2 factor design with the within subject factor work environment (single, multiple baseline (Ba), multiple advanced (Ad)) and the between subject factor traffic distribution (5:1, 3:3, 6:0) was completed. The order in which ATCOs completed the conditions was varied and ATCOs were matched by age to the conditions (5:1) and (3:3) to make the subsamples comparable. Prior to the experimental traffic scenarios, ATCOs completed a training procedure to become familiarized with the work environment, the provided technical equipment and the multiple remote tower work environment. In Table 1 it is depicted that 14 out of 16 eye-data sets were available for each condition (total n=42). In addition, for each eye data set a validity metric was calculated referring to the percentage of eye data unequal to zero or minus one.

<table>
<thead>
<tr>
<th>Number of data-set</th>
<th>Single</th>
<th>Multiple Ba</th>
<th>Multiple Ad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Validity (Min, Max)</td>
<td>60% - 94%</td>
<td>77% - 93%</td>
<td>73% - 95%</td>
</tr>
<tr>
<td>Summary</td>
<td>42 data-set of 60 min each</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

F. Procedure

For each day, two ATCOs were invited. ATCOs completed sessions of one hour on two succeeding days. The first day started with a briefing, followed by the training (about 30 min). ATCOs completed the scenarios in parallel, one controlling traffic for the single remote tower, the other for the multiple remote tower. Only for the multiple baseline condition the ATCOs completed their scenarios sequential in order to have the second ATCO in the role of an expert observer. The instantaneous self-assessment scale was used in two minute intervals for online workload assessment. After each scenario ATCOs had to fill out post-run questionnaires asking for situation awareness, workload and addressing safety aspects. A half-structured interview was then used to get ATCOs feedback for specific traffic situations that occurred during each scenario. On the second day, a final questionnaire was used followed by a final debriefing and a feedback session.

G. Task

The ATCOs were asked to control one or rather two airports at a time while procedures, rules and regulations correspond to the existing regulations for tower control today.

III. RESULTS

A. Dweltimes and Fixations

**Dweltimes.** In all three conditions ATCOs showed highest dweltimes of visual attention on the flight strips, followed by the panorama followed by the radar. The mean values and standard deviations of the percentaged dweltimes for the different AOIs are summarized in Table 02.

<table>
<thead>
<tr>
<th>Area of Interest</th>
<th>Single</th>
<th>Multiple Ba</th>
<th>Multiple Ad</th>
</tr>
</thead>
<tbody>
<tr>
<td>flight strips</td>
<td>32.55 (11.3)</td>
<td>40.68 (10.7)</td>
<td>41.43 (9.9)</td>
</tr>
<tr>
<td>panorama</td>
<td>25.76 (7.3)</td>
<td>21.39 (5.9)</td>
<td>23.88 (7.7)</td>
</tr>
</tbody>
</table>
A 2*2 repeated measurement ANOVA with factors CONDITION (MuAd, MuBa) and TRAFFIC DISTRIBUTION (5:1, 3:3) did not show a significant main effect for TRAFFIC DISTRIBUTION ($F_{(6,7)}<1$, $p=.60$) nor a significant interaction effect COND*TRAF-DISTR ($F_{(6,7)}<1$, $p=.10$). Therefore, the two groups (5:1, 3:3) were treated equal. The following 3 factor repeated measurement MANOVA with the factor CONDITION (MuAd, MuBa, SiBa) revealed a significant main effect on six areas of interest (AOI 1-6 = dependent variables), $F_{(12,2)}=37.64$, $p=.026$). Post-hoc tests reveal that within the single baseline condition ATCOs spent significant less attention on the flight strips compared to the multiple advanced conditions ($p<.05$) and the same trend for the multiple baseline condition ($p=.06$). For the radar, controllers spent significant less attention on the radar in both multiple conditions compared to the single baseline condition. There is no difference of ATCOs visual attention on the panorama. The results for the percentaged dwelltimes are depicted in Figure 3.

Number of Fixations. For the 60 min lasting simulation sessions mean number of fixations are presented in Table 3. There are no significant differences between conditions. While the dwelltimes for flight strips showed significant differences, this is not represented by the number of fixations for flight strips. Also in contrast to the trend that the dwelltime for the panorama is highest, the mean number of fixations for the panorama is lowest for the single baseline condition. The mean values and standard deviations are depicted in Table 3.

Mean Fixation Duration. The mean fixation durations are of main interest for the AOIs panorama, flight strips and radar in order to explain differences in dwell times. The data are represented in Table 4.

<table>
<thead>
<tr>
<th>Area of Interest</th>
<th>Single</th>
<th>Multiple Ba</th>
<th>Multiple Ad</th>
</tr>
</thead>
<tbody>
<tr>
<td>radar</td>
<td>22.91  (5.8)</td>
<td>17.80 (4.1)</td>
<td>16.42 (3.5)</td>
</tr>
<tr>
<td></td>
<td>1.94 (0.6)</td>
<td>2.36 (0.7)</td>
<td>2.68 (0.6)</td>
</tr>
<tr>
<td>radio</td>
<td>1.33 (0.5)</td>
<td>2.37 (0.4)</td>
<td>2.64 (0.5)</td>
</tr>
<tr>
<td></td>
<td>15.48 (6.1)</td>
<td>15.37 (4.9)</td>
<td>12.09 (3.9)</td>
</tr>
</tbody>
</table>

Due to the fact that the differences in dwelltimes for flight strips could not be explained by the mean number of fixations it becomes apparent that for the mean fixation duration on the flight strips an interaction effect AOI*CONDITION ($F_{(4,72)}=3.55$, $f^2=.16$) was found. For the single baseline mean fixation duration on the flight strips is shorter than for both multiple conditions ($p<.01$). For the AOIs panorama and radar, there are no significant differences in fixation durations.

B. Moving average time windows

Visual attention over time. While dwelltimes, number and duration of fixations are often reported to describe ATCOs visual attention for complete simulation runs, these metrics are not very informative about ATCOs visual attention on AOI over time. Calculating moving average time windows (MAWs) is one approach to respect for ATCOs visual attention within smaller time intervals. For the data presented in Table 5 and 6 we calculated MAWs for AOI panorama, radar and flightstrips for 10s and 30s intervals for each simulation run. In a second step, we averaged the MAWs over participants (n=39) per condition (3). For these three data sets (mean(SiBa), mean(MuBa), mean(MuAd)) we afterwards identified for every time interval which of the three AOIs had the maximum value. This way it can be identified for how many time intervals ATCOs main visual attention was on the panorama, the radar, or the flight strips.

<table>
<thead>
<tr>
<th>MAW</th>
<th>AOI</th>
<th>Single</th>
<th>Multiple Ba</th>
<th>Multiple Ad</th>
</tr>
</thead>
<tbody>
<tr>
<td>[10s,1s]</td>
<td>panorama</td>
<td>909</td>
<td>330</td>
<td>399</td>
</tr>
<tr>
<td>[10s,1s]</td>
<td>radar</td>
<td>606</td>
<td>249</td>
<td>158</td>
</tr>
<tr>
<td>[10s,1s]</td>
<td>flight strips</td>
<td>2084</td>
<td>3161</td>
<td>3042</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MAW</th>
<th>AOI</th>
<th>Single</th>
<th>Multiple Ba</th>
<th>Multiple Ad</th>
</tr>
</thead>
<tbody>
<tr>
<td>[30s,1s]</td>
<td>panorama</td>
<td>758</td>
<td>171</td>
<td>211</td>
</tr>
<tr>
<td>[30s,1s]</td>
<td>radar</td>
<td>530</td>
<td>145</td>
<td>61</td>
</tr>
<tr>
<td>[30s,1s]</td>
<td>flight strips</td>
<td>2289</td>
<td>3279</td>
<td>3305</td>
</tr>
</tbody>
</table>
Size of time interval. In Table 5 and 6 two different time intervals were chosen. It becomes clear that the size of the time interval must be defined with respect to the task of interest. The data show that within the single baseline condition, 909 time intervals could be identified in which the averaged maximum visual attention was on the panorama. For the multiple baseline condition only 330 and for the multiple advanced only 399 such intervals could be found. In addition, it can be seen from a comparison of Table 5 and 6 that the numbers with maximum visual attention on the AOI panorama and radar decrease, when the length of the interval is increased from 10s to 30s. On the other hand, the number of time intervals with maximum visual attention on the flight strips increases slightly.

Maximum visual attention. In Figure 4, 2*3 MAW plots over the simulation runs corresponding with Table 5 and 6 are depicted (x-axis: time, y-axis: percentage 0-1). While the dwelltimes and fixations, presented earlier, are an aggregated metric per simulation run, the MAW allows for a higher granularity of controllers visual attention over time and to visualize what the results in Table 5 and 6 mean. The first three graphs report the MAW for the [1s, 10s] interval and the second three graphs for the [1s, 30s] interval. These graphs can be read as a cursor showing controllers’ maximum visual attention over time. It does not mean that controllers’ looked exclusively on that AOI, but that for a defined time window of 10s or rather 30s their maximum visual attention was on a specific AOI. Grey bars stand for maximum visual attention on the flight strips, green bars for the panorama and black bars for the radar. The red line indicates the percentage of valid eye data measures. Looking at Table 5 and 6 and comparing the single with the multiple conditions clearly show that on average there are more time intervals with maximal attention on the panorama or radar within the single baseline condition. For the multiple conditions there are more intervals with maximal attention on the flight strips. This means that there are more time intervals within the single baseline condition in which controllers have their maximum visual attention on the panorama and radar, a result the aggregated dwelltimes and fixations cannot report. This result is not contradictory to the findings reported by dwelltimes and fixations, it is just more informative about controllers visual attention over time. The height of the bars (0-1) represents the proportional visual attention on the AOI. It will be discussed in the next section, in what way this eye data measure can be of interest to characterize controllers monitoring behaviour and how it might help to better define when controllers might be overloaded based on their visual attention capacity.

Figure 4. Percentaged dwelltimes for all three conditions for a time interval of 10s for each second.
IV. DISCUSSION

In this paper it has been addressed in what way moving average time windows might provide valuable analysis to evaluate how controllers monitoring behaviour changes when controlling multiple airports. Furthermore it was of interest to discuss in what way the metric resembles appropriate monitoring behaviour. It was demonstrated how the moving average time window for the maximum AOI can nicely visualize which AOI received controllers’ maximum visual attention for a predefined time interval. In order to evaluate controllers’ monitoring behaviour, it would be possible to quantify how much visual attention controllers’ have left over time to monitor the processes of the airport using the out-of-the-tower view.

A. Multiple Remote Tower: Dwelltimes and Fixations

In the literature, tower controllers head-down times are seen critical, as during these time periods controllers do not have the chance to identify unexpected events that might occur within their control zone [14]. It can be reported by the aggregated measure percentaged dwelltime that controllers spent less attention on the flight strips in the single baseline condition compared to the multiple conditions. This effect is not explained by a higher number of fixations on the flight strips, but by shorter fixations on the flight strips. This effect might be due to that in the multiple conditions controllers experience cognitive demands of allocating the traffic to the according airport. The flight strips include the important information for this task. Although there is no dwelltime effect apparent for the AOI panorama, there is a radar effect showing that within the multiple advanced condition less attention is on the radar screen compared to the single baseline condition. This effect is in line with a former study by Papenfuss et al. (2010) where also no effect was found for the panorama, but reduced visual attention on the radar [15]. In the multiple advanced condition controllers could get the callsign information directly from the panorama, but not in the multiple baseline condition. The reduced visual attention on the radar screen in the multiple advanced condition in this study is rather explained by the multiple condition in general than by the callsign; also because no radar-effect was found comparing the multiple baseline with the multiple advanced condition.

From a human factors perspective integrating the callsign into the panoramic view has two aspects. On the one hand, it is well liked by controllers to have the callsign integrated and close to the aircraft, although it did not show to effect controllers’ overt visual attention. On the other hand no overlays in the panorama ensure that controllers use two independent information sources for verification of the pilot reports. For instance, controllers use the panorama to verify the system state of the aircraft (real time data), while they have to look on the radar to get the callsign information (background knowledge). If both information are integrated permanently in the out-of-the-tower view the phenomenon...
known as attentional tunneling might need further investigation. Attentional tunneling stands for the phenomenon that describes that you don’t see information that is rather obvious, if you are focused due to specific information search [16]. In order to minimize the risk for attentional tunneling due to aircraft label integration, a design note could be to not label aircraft in the final approach phase (or within 2 miles distance to the tower). Not labelling aircraft at the final can support that controllers will check for critical aircraft states (e.g. check gear down) and their attention will not be captured by the aircraft label. Another possible solution to avoid attentional tunneling due to label integration could be realized, by not displaying the labels permanently. Controllers could be asked to press a button to display the labels only for a limited amount of time (e.g. 5 sec).

B. Functional Task Environment and moving average time windows

Areas of Interest. In this study the areas of interest were defined only as functional units, no matter if ATCOs had to control one airport or two airports. This way it was possible to directly compare ATCOs visual attention on the functional units, independent from their experimental condition.

In this paper, not only dwelltimes aggregated over simulation runs were reported. Due to the fact that aggregated measures over simulation runs only report the proportion of visual attention, these measures are not very informative for controllers monitoring behaviour over time. It was demonstrated that moving average time windows provide a valuable visualization of controllers’ visual attention over time. The traffic scenarios within this simulation study were aiming at 6 A/C at-a-time, independent of single or multiple tower control.

C. Discussing the empirical results

In this study, a relative comparison between a baseline condition (single baseline) and the experimental conditions (multiple baseline) have been completed. On average there were more time intervals in which the maximum visual attention was on the panorama, for the single baseline condition compared to the multiple conditions. The MAWs in Figure 4 and 5 show that in contrast to our expectations, also for the single baseline condition controllers’ maximum visual attention was on the flight strips and not on the panorama for most of the time intervals. However, increasing head-down times within simulation studies in comparison to field studies are consistent with the literature e.g. (Papenfuss et al. 2010). For the future, it would be of interest to not only complete relative comparisons, but to have normative reference models for controllers’ visual attention over time (compare Anders request for pilot models [11]).

D. Potential of the metric “maximum visual attention” over time

In order to evaluate novel work environments like multiple remote tower, moving average time windows can complement aggregated measures, such as dwelltimes and fixations. In the introduction it was mentioned that there is this rule of thumb for tower controllers’ workplace that controllers should look out of the tower as often and as much as possible. However, it remains unclear what this means.

The authors of this paper assume that the limited visual attention capacity of a controller is one crucial factor for how much traffic, or how many airports a controller can be responsible for. While there are a lot of inter-individual differences in fixation sequences and scanpaths of controllers, we see the potential that beside these inter-individual differences, it should be possible to define, how much visual attention resources a controller should have available on the outside view, to detect unexpected events within the control zone of an airport.

It has to be discussed in what way it is acceptable for the tower control task if heavy traffic load provokes long time intervals with maximum visual attention on the flight strips. Such behaviour might indicate that controllers are not updating their current traffic picture and are more engaged by other cognitive subtasks, such as searching for future potential conflicts or switching attention or general information processing, like strip marking.

As head-down times over a longer time period bear a great potential for missing critical events in the bottom-up driven work environment, it might be of interest to define how much visual attention resources controllers should have left for monitoring the out-of-the-tower view. For the evaluation of new work environments in the future, it would be of great interest to compare these empirical eye-data values with a normative reference model. Values for the reference model should be derived from System Matter Experts (SME), or might be generated using computational models such as Wickens’ N-SEEV model [17]. It should be also discussed with system matter experts, how to set the parameters.

Setting the parameters. Choosing larger moving average time intervals (e.g. a 30 s time interval) is rather liberal as it allows for longer time periods of not looking at a certain AOI at all, but still being the AOI with maximum visual attention.

In contrast, a smaller time interval (e.g. 10 s) is rather conservative as it would define that the time interval in which controllers’ visual attention is not on a certain AOI at all is rather short. These parameters therefore must be discussed and adopted to the demands of the task under investigation.

V. CONCLUSION & OUTLOOK

It will be of interest for future concepts in air traffic control, like the concept for multiple remote tower, how to evaluate, whether controllers’ are able to perform their monitoring and control task sufficiently. In this paper, it was introduced in what way an analysis of the visual attention of controllers can provide valuable access to characterize controllers’ monitoring. It will be of interest for future research to define normative models that capture the expectations of visual scanning behaviour for tower controllers. From our understanding the approach of moving average time windows might provide a robust approach for defining measures and parameters that are stable over inter-individual differences.

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