Identifying Operators Monitoring Approriately

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ABSTRACT

The objective of the presented study was to identify monitoring behaviour parameters for the purpose of prediction of manual control performance in the area of aviation. In other words: we want to distinguish between good and bad aviation operators. For this reason we developed an air traffic flow simulation tool (SSAS: Self Separation Air Space Simulation) that represents future tasks of pilots and controllers. 90 applicants of the Deutsche Lufthansa AG (DLH) und the Deutsche Flugsicherung GmbH (DFS) performed scenarios of different complexity. Preliminary to the manual control of each scenario, the applicants monitored the same scenario whereas the simulation was operating automatically. Eye movement data were collected while monitoring in the automatic part of the simulation. These data were connected to manual performance data. Results of our Study show, that in tasks of moderate complexity and difficulty, appropriate monitoring behaviour is related to efficient manual control afterwards.

Author Keywords

Monitoring behavior, air traffic flow simulation, prediction of manual control.

INTRODUCTION

Research project Aviator 2030 (see Fig. 1) focuses on an optimal fit between air traffic management (ATM) system design and human operators in future aviation. This will be carried out by adapting selection profiles to future ability requirements. In the first project phase, workshops with experienced pilots and air traffic controllers were conducted in order to develop a concept of future ATM. They were asked to tell their expectations regarding future tasks, roles and responsibilities. Summing up these workshop results, monitoring and teamwork in a highly automated workplace pose a challenge to future aircraft operators (Bruder, Jörn & Eißfeldt, 2008). Thus, research should focus on the ability of monitoring as one major topic. The second project phase comprised the development of simulation tools that represent future workplaces in aviation. Experiments with humans operating in these simulated future workplaces serve as basis for identifying potential changes in ability requirements for pilots and air traffic controllers. Results allow for a timely adjustment of selection profiles and, thereby, for the development of future ability tests.

METHOD

Based on the empirical background (for a detailed explanation see Hasse et al., 2009) we devised a normative model, which describes the monitoring behaviour of operators monitoring appropriately (OMA). According to models of adequate and efficient monitoring behaviour (Niessen & Eyferth, 2001) as well as differences between experts and novices (Underwood et al., 2003) it can be stated that OMA show target oriented attention allocation in general as well as during monitoring phases (orientation – anticipation - operation - debriefing). Whereas the first assumption requires the operator to adapt attention allocation to the specific requirements of a given situation in general, the second assumption focuses the allocation of attention in phases. The operator is required to demonstrate flexibility in:

- anticipating system operations (during anticipation phases)
- detecting relevant system operations (during operating phases)
- controlling system performance afterwards (during debriefing phases)

We further assume that "good monitoring" is associated with an accurate manual system handling in case of automation failure, and therefore aim to connect monitoring behaviour with manual control behaviour. We assume that

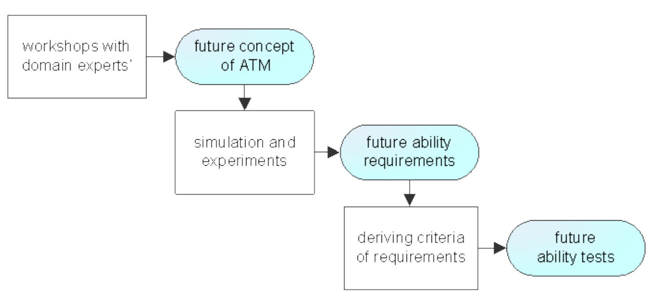

Figure 1. Flowchart of the Aviator 2030 Project.

this link reflects differences in understanding of the underlying principles of the automatic system. The question we need to answer is: which monitoring criteria are most important with regard to identifying OMA that have the ability to manually control the system? In order to answer this we aim to test the following hypotheses:

Hypothesis 1: Keeping an overview of the overall automated system during an entire monitoring run is related to an accurate manual control of the system in case of necessity.

Hypothesis 2: Anticipating and detecting important automated system operations in time as well as controlling them is related to an accurate manual control in case of necessity.

Simulation Tool

With the objective of identifying monitoring parameters that have an impact on manual system handling, we developed a simulation tool that allows for the assessment of monitoring performance. The SSAS is a simplified air traffic flow simulation, where two tasks have to be performed – a traffic flow simulation and a simple flight control simulation. SSAS software is running on any WIN XP (minimum requirement: SP2) or WIN Vista pc configuration equipped with a DualCore processor. The graphical user interface (GUI) is designed for any screen sizes with resolutions varying from 800x600 to 1600x1200. Handling of the simulation will be carried out by mouse or touch screen.

Concerning the first task, operators have to manage the traffic flow between two airports – east and west - each consisting of an inbound and an outbound area (see Figure 2). At these areas values of the traffic load are depicted. The *target* value shows, how many aircraft should stay at this area. In the course of the simulation the target values remain unchanged. The *actual* value displays the actual number of aircraft staying in the corresponding area. The task of the operator is to bring all actual values into agreement with the target values of the corresponding areas as soon as possible. Additionally, there are exit and entry areas. These areas simulate extern air spaces which can’t be controlled by the operator.

The outbound and inbound areas are connected by four different types of routes: air routes (between inbound and outbound of different air ports), exit routes (between inbound and an external air space), access routes (between an external air space and outbound) and service routes (between outbound and inbound of the same airport). Every route is a one-way road, the traffic flow is unidirectional, e.g. on air routes aircraft only move from the outbound area to the inbound area. Between the inbound and the outbound area of different airports there are two routes of different capacities and velocities. The upper route is capable of twice as much aircraft as the lower one. On the other hand,

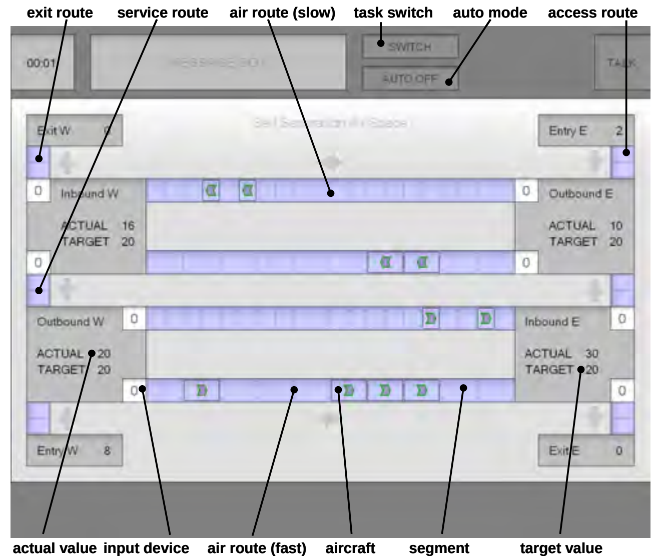

Figure 2. Air traffic flow display of the SSAS.

aircraft moving on the lower route are two times faster than aircraft on the upper route.

Operators can handle and control the system via input devices (white buttons). Left-click on an input device will increase the number of announced aircraft (maximum: five aircraft), which will use the corresponding route in the next time units. A right click on the input device will diminish the number of annunciated aircraft (minimum: zero aircraft). Each time unit (configurable, in this simulation one time unit equals two seconds) announced aircraft will be released on the routes, at a frequency of one per route and time unit. When an aircraft is released on a route (green arrow), the number of announced aircraft at the corresponding input device is reduced by one. Some routes can’t be controlled by the operator: the two access routes are feeding traffic into the simulation automatically. This feature assures, that an overall system work load can be maintained. Cleared aircraft move to the next segment of the route each time unit. When an aircraft arrives at the designated area on the other side of the route, the actual value of the corresponding area will be increased by one. As mentioned before, goal for the operator is to equate all actual values to the corresponding target values.

Sometimes aircraft are critical, i.e. they do not flight optimally in the airway (green frame of the aircraft symbol changes to a red frame). In this case, operators have to navigate the critical aircraft back on the optimal pathway as soon as possible. To perform this task, the operator must switch to the flight control screen (see Figure 3) by pressing the switch button.

On this screen a detail of the critical air route is displayed, consisting of some segments of the air route and the critical aircraft. Furthermore, performance indicators and adjustment devices for the vertical and horizontal

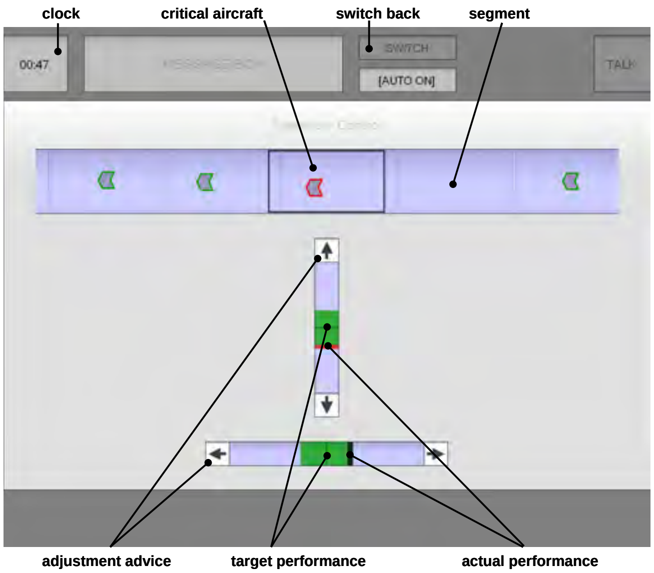

Figure 3. Flight control display of the SSAS.

performance of the aircraft are depicted. The actual performance indicators, displayed by small red and black bars, show the actual performance of the aircraft. A red bar indicates a need for performance improvement, a black bar symbolizes an acceptable performance. The target performance indicators, depicted as large green bars, mark the desired performance, whereas the target performance indicators are fixed. If a red bar appears, it has to be moved into the green bar. This can be done by simply clicking on the relevant adjustment devices on the screen. Every click on the device will correct the aircrafts pathway towards the target performance. When the target performance is reached, the operator can switch back to traffic flow simulation. In short, the operators' task is to control the traffic flow between two airports. The operator either monitors an automatic process or controls the traffic manually, allowing us to collect data on their performance of both types of task separately. With the objective of varying complexity and dynamics of the automatic system, we developed four scenarios reflecting different degrees of difficulty. The four scenarios were presented in a fixed order for every subject, beginning with the easiest (scenario 1), finishing with the most complex (scenario 4).

Measurements

As for dependent variables, we focus on the establishment and maintenance of system understanding during the monitoring phase. We use eye movement parameters, which act as indicators for the perceptual and cognitive operations involved. Monitoring performance was measured by recording eye movements. We used relative fixation counts and mean fixation durations based on predefined areas of interest. Fixation counts can be used as a measure of expectations and assumptions of the person (Rötting, 2001), where important objects are likely to be fixated upon more often than less important ones (Göbel, 1999). Fixation durations can be used as measure of information processing duration (Inhoff & Radach, 1998, S. 37, cit. in Rötting, 2001). Accordingly, processing difficulty as well as personal strain is reflected in the fixation duration (Rayner, 1982, Balota et al., 1985).

Our normative model postulates that OMA keep an overview of system operations during an entire monitoring run; in this experiment during the automatic mode of one scenario (hypothesis 1). Moreover, OMA are expected to anticipate, detect and control automated operations in time; in this experiment reflected by different operations performed by automation within the automatic mode of one scenario (hypothesis 2). As for testing the first hypothesis, we defined scenario specific areas of interest (AOIs), that is areas on the simulation screen that we expect to be pre-conditional for keeping an overview of system behaviour. As for testing the second hypothesis, we determined AOIs that help to anticipate and detect system operations as well as to debrief them. As anticipation, detection and debriefing of system operations are only possible within definite time frames within a scenario, we cut every scenario into time frames. Every time frame stands for a monitoring phase and is characterised by AOIs being conditional for monitoring adequately in this phase, e.g. anticipating a system operation adequately. Hence, this model leads us to expect eye movements on areas of interest that are generally relevant for a specific scenario as well as for monitoring phases within specific time frames. As we assume the understanding of the system to be conditional for manual system handling in case of system failure, we combine both, eye movement parameters and performance data, as measurements. Regarding the performance of a test subject during the manual phase of each scenario, we used the mean deviation of actual values from target values of in- and outbounds. To avoid the possible impact of a general ability on manual performance when controlling a system, we corrected manual performance by deducting the baseline measurement when both parameters are significantly correlated. Eye Movements are recorded by Eyegaze Analysis System manufactured by L. C. T.. Managing of raw data was conducted by NYAN software, developed by Interactive Minds. Subjects were seated in front of a 19-inch LCD computer display with a distance of approximately 60 cm.

Procedure

90 participants from DLH and DFS were tested individually. First, they were given a questionnaire measuring trust in automation, and the instruction for the following experiment. Participants were told that they would work on four scenarios, all consisting of two phases starting with an automation phase followed by a manual phase. Referring to the automation phase they were instructed to monitor the automation with the objective of understanding the rule-based dynamics of the given scenario. Referring to the hand control phase (manual condition), participants were

assigned to manually control the system in continuation of the automation. That is, participants should control the system in terms of the rules and dynamics that they have learned from monitoring the scenario in automation. After a short (15 s) calibration phase that ensures adjustment of Eyegaze Analysis System to individual gazes of the participants, the persons were then presented the four scenarios, each taking 5 minutes. There was a smooth transition between the automatic mode and manual mode within each scenario but pauses were placed between each scenario. The four scenarios were presented in a fixed order for every subject beginning with the easiest, scenario 1, finishing with the most complex, scenario 4.

RESULTS

Our results show, that high performers look frequently at relevant areas to keep an overview as well as to detect and to recheck tasks in time. In addition, high performers look relatively long at relevant areas during orientation towards the scenario.

Overall, relative fixation counts on scenario and phase specific areas seemed to be an adequate parameter in order to identify OMA. The better subjects keep an overview of system operations (while monitoring automated processes), the better their ability to resume manual control. Furthermore, the better they are shifting their attention to timely relevant actions, the better their ability to resume control manually.

During orientation phases, gaze durations instead of fixations counts seem to be the appropriate parameter to predict the ability to resume manual control. The longer test subjects look at relevant areas, the better their manual performance in the manual phase.

During orientation phases the simulator screen is "frozen", so it would make sense to look persistently at relevant areas (while events remain static). On the other hand, it could be shown that frequently looking at relevant areas while events are changing dynamically is an appropriate monitoring behaviour, too.

Overall, it could be shown with SSAS that monitoring parameters have predictive power for system understanding and performance on the task.

Results are dependent on difficulty of scenario and phase, with scenario 1 being too easy and scenario 4 being too difficult.

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