Comparison of methods for studying air traffic controller's information strategies

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1. Introduction

In the field of human-machine systems the development of machines on higher levels of automation has changed the task allocation between human and machines. The human task in the overall system is increasingly stamped by monitoring and control demands. Thus, the focus on analysing and evaluating e.g. the performance of human-machine systems has been relocated from observable behaviour to cognitive processes and the mental representation of the controllers. Therefore, researchers are looking for methods to obtain the insights in the mental processes of the controllers. But, unfortunately, most of available methods interfere or disrupt the controller's task completion. Eye movement measurement can be applied in a non-invasive manner and is usable to record data in a very high resolution. In an instructed task environment eye movement data are related to the orientation of visual attention and the information currently processed in mind. Another method, the so called demasking technique, was used in a similar way to investigate information demands in the air space simulation. The investigation was conducted to decide which of the two methods should be used for future investigation: eye tracking or demasking technique.

2. Materials and methods

Eye movement measurement and the demasking technique were used to investigate air traffic controllers information pick up within a simulated programmable airspace setting, the "EnCoRe PluS" – system (fig. 1), a realistic simulation of a radar controller's workplace (Bierwagen 1996).

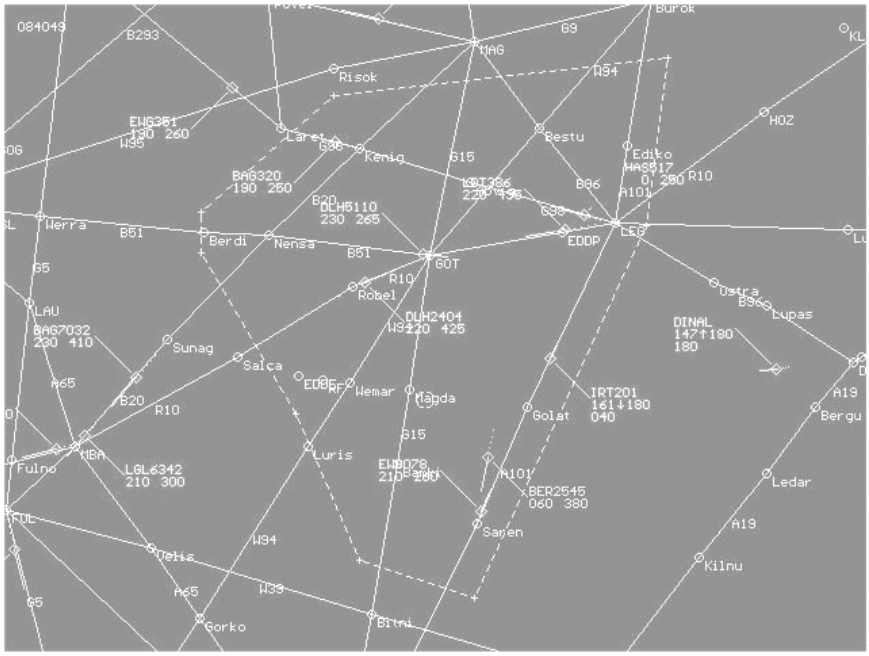

Figure 1: Screenshot of the "EnCoRe-PluS" – system with controlled aircraft (green target with alphanumeric label), control sector (grey dotted line), and air traffic routes (grey lines)

Two flight scenarios were programmed in EnCoRe-PluS with similar traffic trends. The aircraft were clustered into four categories: descent, ascending, conflict, and incoming. Seventeen en-route air traffic controllers from the regional control centre in Berlin-Tempelhof worked on the scenarios. All participants worked under eye tracking condition and demasking technique condition. After the trials a questionnaire was presented to rank the task demands under the trial conditions and the preferences of the participants for one of the methods to evaluate the acceptance for the future application of the methods.

With the demasking technique meaningful alphanumeric information in the label of the aircraft on the radar screen were masked with grey bars. The underlying information could be unmasked by a mouse cursor action. (The demasking of a specific field of the label information of an aircraft indicates the necessity of that specific information for the current control process similar to a gaze on the label.) The demasking data were logged in the simulation system for automatic data analysis. In the eye tracking condition all information was visible during the control task. In the air traffic control simulation the ISCAN system with remote unit was used to record eye movements. The remote unit was placed in front of the radar screen vis-à-vis to the subject. The system was able to follow head movements to left and right in a range of app. 30 degrees (Franke 1995). The ISCAN-system was based on a point-of-regard-measurement technique with a sampling rate of 50 Hz. The fixations, when the eye is focused on an object, were analysed off-line from the ISCAN data automatically with a time criterion of 100 ms and a local criterion of 1 degree of visual angle. The manual data analysis for eye tracking data is very laborious, especially for dynamic objects like moving targets on a radar screen. For efficient data analysis of gazes on the moving aircraft targets the replay of the simulation system was used. The fixation data were inserted as mouse cursor co-ordinates into the simulation running with demasking technique. When a fixation hit a masked bar it was logged like mouse actions from the air traffic controllers. The logfile protocol from the demasking actions for each object category was compared with that from the fixation data.

3. Results

Mean duration and mean frequencies of observation of the objects shows that eye tracking and demasking technique produce different overall values, but for both conditions: “gaze” and “demasking” a category dependent effect exists (fig. 2 and 3).

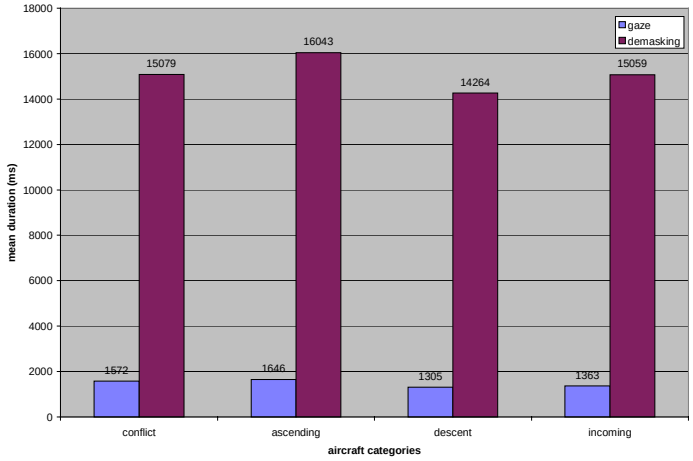

Figure 1: Mean duration of observations of aircraft of the four categories

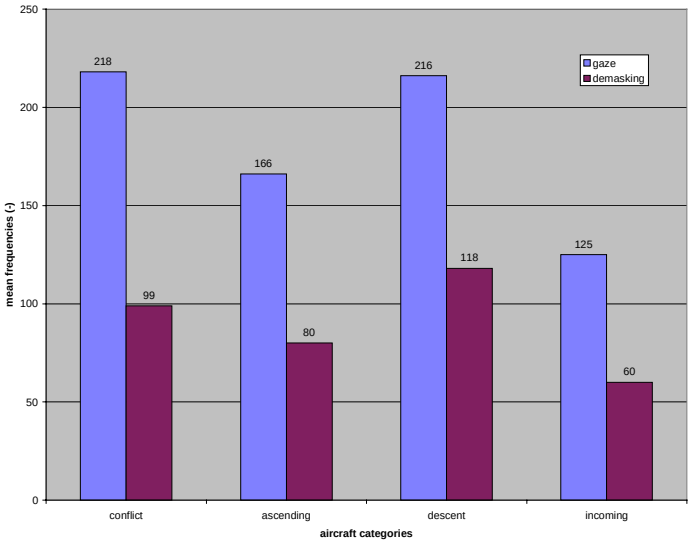

Figure 2: Mean frequencies of observation of aircraft of the four categories

The mean observation duration is highest for ascending aircraft, followed by conflict, and lower for incoming and descent aircraft. For conflict and descent aircraft the mean observation frequencies are highest, for ascending and incoming aircraft mean observation frequencies are lower.

The differences of mean duration between the aircraft categories did not achieve statistical significance. The differences of mean frequencies of observation for demasking condition were statistically significant (Friedman-Test; $p<.001$). Statistical significance failed in the gaze condition for the categories conflict and descent aircraft.

The analysis of the questionnaire of acceptance shows method dependent results: 90 percent of the air traffic controllers ranked the simulation scenario as better predictable if it was controlled under the gaze condition than under the demasking condition. All participants reported that fulfilling their control task was easier under the gaze condition.

4. Conclusion

The comparison of the demasking technique and eye movement measurement let conclude that both methods are able to register information intake and lead to a similarly reasonable interpretation in the context of air traffic control. Even though numerical values are different, the affinity between the semantic related categories under both conditions is apparent. Data from both methods seem to be related to the same mental processes. Thus, in order to chose one of the methods for future investigation practical aspects like acceptance should be considered: In the study presented here, acceptance was better for eye movement measurement than for the demasking technique. Still, for efficient data analysis automated procedures for eye tracker evaluation are necessary. Automatic synchronisation between the air space simulation and the eye tracker will improve the quality of the measurement compared to offline manual synchronisation of data protocols.

5. Literature

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