Making the invisible visible - increasing pilot training effectiveness by visualizing scan patterns of trainees through AR

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Abstract - This paper describes the development and evaluation of a scan pattern monitoring system using augmented reality. The system enables instructors to monitor scan patterns of pilots by non-intrusively tracking the pilot's eyes and displaying the scan patterns to the instructor through augmented reality. Subject matter experts (pilot instructors) evaluated this application as a support for the debriefing. Further development should focus on creating a tablet version for use during the debriefing and on the best ways to implement this in pilot training.

1 Introduction

Scanning the environment or a system's status in a routine pattern is an important aspect of an operator's ability to perform continuous control tasks or monitoring tasks, such as flying an aircraft or controlling air traffic. During approach, it is important that pilots gradually shift their attention from information on the Primary Flight Display (PFD, located on the cockpit display) to the outside windows [1]–[3]. Effective scanning can be difficult to learn [4] and insufficient scanning can be the root cause for a variety of performance issues. Once ineffective scan patterns have been routinized they are very hard to correct. This can lead to student attrition in a very late stage of an expensive training program.

Despite its importance, current training systems lack objective information about students' scan patterns. Pilot instructors can base the feedback gathered during a training session only on 1) the results in the simulator, 2) students' movements in the simulator, and 3) by asking questions about flight parameters to check if they have been scanned. This means that they cannot entirely be sure if these results are based on whether the pilot did or did not perceive a relevant situation (change of speed, altitude, etc.), whether the pilot noticed a problem, and/or whether the pilot knows the appropriate action [5]. Available information concerning scan patterns is indirect and limited, which makes root cause analysis of performance issues difficult for the instructors.

Objective information regarding students' scan patterns could eliminate this lack and uncertainty of information. Instructors consequently indicate that eye-tracking could be a useful tool to improve training and/or flight safety [6]–[8] and some researchers have tried to create such a training tool [5]–[8]. However, these attempts failed because the eye-trackers were too intrusive or the tool was not advanced enough for optimal functioning. None of these studies used real-time presentation of the eye-tracking data.

This study investigates a non-intrusive scanning system that aims to enable instructors to monitor students' scan patterns in real-time to facilitate root cause analysis of performance.

2 Materials and Methods

A short questionnaire was distributed among a group of experienced instructors (n=20) to determine whether pilot training would benefit from objective information about pilot scan patterns.

Subsequently, an augmented reality (AR) scanning system was designed to visualize the students' scan patterns. All concepts created during the development phases were evaluated by subject matter experts. The information retrieved from the results was used as input for the creation of a following concept. The first concept focused on the real-time visualization, the use of colors and the choice of technology / medium used for presentation. In a second concept the presentation of processed data was added. The third concept dealt with the translation to a working prototype: a software application was created to visualize the eye tracking behavior - as measured by a remote eye tracker - in an AR headset (Microsoft HoloLens, with a Field Of View of 35 degrees).

The usability and potential support of this prototype was evaluated by five instructor pilots using the User Experience Questionnaire [9]. The application was evaluated by training unexperienced pilots to manually fly an approach and landing in NLR's B737 research simulator.

3 Results

The results from the questionnaire confirm the results of earlier studies that instructors have a demand for monitoring their students' scan patterns.

Results of the test indicate that instructors felt supported by the tool to provide feedback to students.

Furthermore, user experience of the tool was evaluated as 'above average' to 'good', with higher scores regarding the novelty and experienced support for the training. According to this small sample of instructors, the tool was intuitive to use, was an improvement of the training and did not impact the instructors' workload. All five instructors would implement a similar tool in their training and recommend it to others.

According to the instructors, this application could be useful for training pilots with every experience level. All instructors thought the application would be useful during approach and landing training for novice pilots. The application could also be used on more experienced pilots when training emergency situations, crew resource management (CRM), or specific persisting flight performance issues. Most instructors agreed that the tool could especially be useful for certain parts of a training, where specific scan pattern behaviors are needed.

The pilots did not have any problems with the application.

Further development may focus on personalizing the tool to the instructors' needs. Instructors suggested an option to select the presentation of eye-tracking related data. A larger field-of-view when looking through the AR headset was a high priority requirement.

4 Lessons learned

The augmented reality application is appreciated by instructor pilots and does seem to support the instructor in monitoring students' scan behavior and in performing root cause analyses. The tool needs further development and validation, but appears to be a promising addition to pilot training.

The presentation of the eye tracking data should be intuitive to interpret and might differ depending on the training case. During an approach and landing, the outside windows are an important area of interest. In other situations these outside windows are less important to look at, for example when experiencing an engine failure. The preferred scan behavior is different in these scenarios, which might influence the optimal data presentation.

5 Future work

The tool requires further development and testing. For sharing eye-tracking information with the student during the debriefing, the application could therefore be extended to a tablet version that includes a playback option. The presentation of the data should be tested with several different visualizations and offer the instructor option to choose the preferred data visualization.

It would be interesting to connect EEG measurements to the system in order to monitor students' workload.

We envision further development to be more effective when prototypes are used in actual training and using a larger group of instructors for the CD&E cycles.

6 Conclusions

An innovative AR application that enables instructors to monitor scan behavior of pilots was developed and tested. Participating instructors are confident this supports them in their debriefing and that using this application can result in a more efficient training.

Acknowledgements

We would like to thank Jeroen van Rooij, Jaap Groeneweg, Bart Helleman and Utrecht University for their contribution to this study.

References

[1] G. Anders, 'Pilot's Attention Allocation During Approach and Landing - Eye- and Head-tracking Research in an A330 Full Flight Simulator', *Ohio paper*, pp. 1–6, 2001.

[2] D. L. Brown, H. S. Bautsch, P. A. Wetzel, and G. M. Anderson, 'Instrument Scan Strategies of F-117A Pilots'. Logicon Technical Services Inc. Dayton OH., 2002.

[3] O. Lefrancois, N. Matton, G. Yves, V. Peysakhovich, and M. Causse, 'The role of Pilots' monitoring strategies in flight performance', *European Association for Aviation Psychology Conference EAAP32*, p. 12, 2016.

[4] E. Dubois, C. Blättler, C. Camachon, and C. Hurter, 'Eye Movements Data Processing for Ab Initio Military Pilot Training', in *Intelligent Decision Technologies*, vol. 39, R. Neves-Silva, L. C. Jain, and R. J. Howlett, Eds. Cham: Springer International Publishing, 2015, pp. 125–135.

[5] M. Carroll *et al.*, 'Enhancing HMD-Based F-35 Training through Integration of Eye Tracking and Electroencephalography Technology', in *Foundations of Augmented Cognition*, vol. 8027, D. D. Schmorrow and C. M. Fidopiastis, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2013, pp. 21–30.

[6] E. A. Henneman *et al.*, 'Eye Tracking as a Debriefing Mechanism in the Simulated Setting Improves Patient Safety Practices':, *Dimensions of Critical Care Nursing*, vol. 33, no. 3, pp. 129–135, 2014.

[7] P. O'Meara *et al.*, 'Developing situation awareness amongst nursing and paramedicine students utilizing eye tracking technology and video debriefing techniques: A proof of concept paper', *International Emergency Nursing*, vol. 23, no. 2, pp. 94–99, Apr. 2015.

[8] P. A. Wetzel, G. M. Anderson, and B. A. Barelka, 'Instructor Use of Eye Position Based Feedback for Pilot Training', *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 42, no. 20, pp. 1388–1392, Oct. 1998.

[9] M. Schrepp, 'UEQ_English.pdf'. https://www.ueq-online.org/, 2008.

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