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Did you see what your trainee pilot is seeing? Integrated eye tracker in the simulator to improve instructors' monitoring performance

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This paper takes the instructor's perspective in investigating whether integrated eye tracking technology with De-Briefing Facilities (DBF) could be used to assist in identifying trainee pilots' operational errors and enhancing instructors' monitoring performance. Nineteen qualified instructor pilots participated in this research. The ages of participants range from 33 to 67 years ($M=48.1$, $SD=9.1$); total flying experience are between 3,600 and 20,000 hours ($M=9,379.0$, $SD=4,708.7$). The results revealed that most of instructors did feel eye tracker providing sufficient and specific information to assist them on the de-briefing. Moreover, some of instructors admitted that by utilizing eye tracking information, they spotted more inappropriate operational behaviours committed by trainee pilots than they otherwise would. Although integrating eye tracking information will also increase the volume of data for instructors to interpret, it can facilitate their monitoring performance of significant operational behaviours and help to direct instructor attention. The eye tracker can be regarded as a positive instructional tool to improve instructor performance in monitoring, scanning, identifying and reviewing operational errors in the flight simulator.

Keywords & Phrases: Air-to-Air Refueling, Attention Distribution, Eye Tracking, Training Evaluation, Visual Behaviours

1 BACKGROUND

In order to fly an aircraft, a pilot must be able to both monitor and actively check the systems they are operating. Military pilots of the air tanker A330-200 Voyager have to pay attention to all parameters in the flight deck and keep an open eye to the operational environment in order to minimize the risks during air-to-air refueling of fighters (Figure 1). The attention distributions and situation awareness (SA) are critical to the safety of flight operations. Lavine, Sibert, Gokturk, and Dickens [1] suggest that visual attention is a precursor to initiating the cognitive process and a pilot's visual scan pattern is closely associated with their attention distribution and SA. Ineffective attention distribution may induce accidents. Asiana Airlines Flight 214 crashed in 2013 on the final approach to San Francisco International Airport. The investigation found that this was in part due to the pilots' lack of situation awareness of the airspeed indicator [2]. Military pilots' attention shifts play a central role in the monitoring task: How and where to commit attention is critical to the quality of visual attention and links to the task in hand. Eye movement is one of the methods for assessing pilots' cognitive processes, based on real-time physiological measures. Therefore, applying an eye tracker to measure visual parameters may serve as a window to explore pilots' attention distribution and SA during flight operations [3, 4].

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Figure 1: The air tanker A330-200 performing air-to-air refueling to the fighters.

The path of visual attention in the flight simulator can reveal pilots' cognitive processes in terms of human-computer interaction [5, 6]. Therefore, information collected through eye tracking has potential not only for pilot training but also for flight deck design evaluation [7]. To apply eye tracking technology in the context of monitoring tasks, it is necessary to understand pilot scan patterns relate to task performance, such as how pilots guide their eye movements during different operational phases and how eye scan patterns change during unexpected situations [8]. High fidelity flight simulators can record and playback almost every element of a simulation to aid instruction and improving training efficiency. However, a limitation of the current generation of flight simulators is that they cannot monitor where a pilot fixated precisely. As a trainee pilot faces forwards in a simulator, their face generally can't be seen by the instructor, who will normally be sat behind them. An instructor may therefore miss the opportunity to identify poor scan technique or a loss of SA which in turn reinforce negative learning and ultimately a normalization of deviance in terms of bad practice.

There has been a lot of eye tracking research utilising flight simulators as a pilot training apparatus. However, none of eye tracking equipment manufacturers or operators have yet been certified based on the Federal Aviation Administration's (FAA) Part-60 Flight Simulation Training Device Qualification Performance Standards. Some airlines (e.g. Emirates and Qantas airlines) are keen to develop simulators with eye-trackers integrated for training, but are still at the developing and testing stage. Furthermore, there is limited research which has investigated how instructors respond to the application of this technology. The majority of eye tracking research focuses on addressing pilots' visual behaviours and application for the purposes of human-computer interaction and flight deck design. What use is all the data in the world, if it can't be effectively interpreted? This paper takes the instructor's perspective to investigate whether integrated eye tracking technology with De-Briefing Facilities (DBF) could be used to assist in identifying trainee pilots' operational errors and enhancing instructors' monitoring performance. In simple terms, the research objective is to ascertain, using eye-tracking, whether instructors can better identify what a trainee pilot was checking and whether it was at the correct moment.

2 METHOD

2.1 Participants

Nineteen qualified instructor pilots participated in this research. The ages of participants range from 33 to 67 years ($M=48.1$, $SD=9.1$); total flying experience between 3,600 and 20,000 hours ($M=9,379.0$, $SD=4,708.7$); and experience on the particular aircraft type was between 900 to 8,000 hours ($M=2,484.2$, $SD=1,790.8$).

2.2 Apparatus

Eye Tracker. A light-weight eye-tracking device “Pupil Pro” which consists of a headset including two cameras for eye movement data collection and analysis (Figure 2). The headset hosts two cameras; one facing the right eye of the participant (eye-camera) which has a resolution of 800 x 600 pixels and a frame rate of 60 Hz; the other capturing the field of vision (world-camera) and which has a resolution of 1920 x 1080 pixels and a frame rate of 60 Hz. These two cameras can be synchronized after calibration. The eye-camera is adjustable to suit different wearers’ facial layout and track their pupil parameters accordingly [9].



Figure 2: Instructor pilot conducting trials by wearing Pupil Lab eye tracker in the Voyager flight simulator.

Flight Simulator. The A330-200 Voyager flight simulator developed by Thales provides state-of-the-art military avionics, mission systems and to Air Tanker. Thales has also provided ground mission training systems, including a full-flight simulator together with other training devices and services for aircrew. The De-Briefing Facilities (DBF) are shown in Figure 3 and comprise a desktop computer and combination of monitors and speakers linked to the flight simulator. The layout of consoles on the DBF is as follows: Section-1 is the screen of eye scan patterns related to training pilots’ attention distributions, this is an additional display will be shown to instructor pilots at phase-3 of the experiment; Section-2 is a speaker; Section-3 reproduces cockpit instruments relating to all flight parameters; Section-4 is the flight deck view that can be seen by pilots; Section-5 is the view of rearward facing camera; Section-6 is the view of simulator camera.



Figure 3: The layout of De-briefing Facilities in the A330-200 Voyager flight simulator.

2.3 Research Design

The eye tracker was worn by the right-hand seat pilot, who in this scenario was acting as the monitoring pilot (PM). The aim was to record the scenario of pre-landing configuration. All participants went through the same scenario and the same procedures which consisted of three phases. The first phase was pre-DBF exposure; the second was post-DBF exposure without eye tracking augmentation; and phase three was post-DBF with eye tracking augmentation. To evaluate the effectiveness of the integrated

eye tracker in the DBF console, the three phases were accompanied by evaluation 9-point Likert scale questions which sought to establish the instructor pilots' opinions on the efficiency of the flight simulator and DBF as an environment in which to identify pilots' operational behaviours (including errors and omissions). For the data collection, each participant was seated at a table in front of DBF screen and asked two questions as follows: "How many of a pilot's actions do you now think you can monitor during simulation?" and "How many of a pilot's actions do you think you can review using the simulator DBF?".

3 RESULTS

3.1 Sample Characteristics

Scores from ratings related to participants' monitoring and reviewing performance based on three phases (pre-DBF, post-DBF, and post-DBF & ET) were analyzed by one-way repeated measures ANOVA. The assumption of sphericity was verified using Mauchy's test, and the Bonferroni test was applied to perform pairwise comparisons after a significant overall test. Effect sizes of samples were quantified by partial eta square (η^2). The descriptive of sample characteristics were shown as Table 1.

Table 1: Means and standard deviations related to participants' monitoring and reviewing performance based on three phases

Question	Phase	N	M	SD
How many of a pilot's actions do you now think you can monitor during simulation?	Pre-DBF	19	5.79	0.92
	Post-DBF		5.58	1.07
	Post-DBF & ET		5.58	1.50
How many of a pilot's actions do you think you can review using the simulator DBF?	Pre-DBF	19	6.95	1.43
	Post-DBF		6.47	1.47
	Post-DBF & ET		7.53	1.31

3.2 Monitoring and Reviewing Performance

Monitoring Performance. There is no significant difference in instructors' scores for monitoring performance in three phases, $F(2, 36) = 0.37$, $p = 0.69$, $\eta^2 = 0.02$ (Figure 4).

Reviewing Performance. There is a significant difference in instructors' scores for reviewing trainees' performance in three phases, $F(2, 36) = 8.35$, $p < 0.01$, $\eta^2 = 0.32$. Furthermore, Post-hoc pairwise Bonferroni comparison revealed that the instructors reviewing trainees' performance based on post-DBF with eye tracking information ($M=7.53$, $SD=1.31$) is significantly higher ($p < 0.01$) than the post-DBF without eye tracking information ($M=6.47$, $SD=1.47$) (Figure 4).

4 DISCUSSION

4.1 Eye Tracking Technology Optimizes Instructors' Allocation of Attention Resources

The quantity of information exposed to the instructor increased from phase-1 to phase-3. The results of one-way repeated measures ANOVA show that instructors reviewing trainee pilots' performance is not in a straight upward trend. Instructors appreciated the augmented information about trainee pilots' visual scan patterns, which in turn facilitated their performance in identifying operational errors.

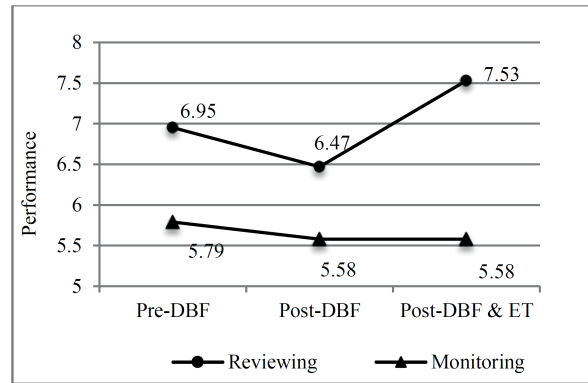


Figure 4: The differences of monitoring and reviewing performance among three phases.

Instructors felt they were less able to identify trainees' operational errors, having just seen the DBF in action compared with directly observing trainees' operational behaviours. An explanation for this fall is that on exposure to the DBF and the excess of information that is available, instructors were unable to monitor all the data at once and were thus prone to missing operational errors. Sometimes, more information creates distraction as human beings suffer limitations in terms of cognitive resources to process all information, either relevant or irrelevant to the tasks in hand [10]. Although the DBF is an outstanding facility, instructors were generally of the opinion that they could get overloaded with data. Attentional resource theories have made a common basic assumption regarding monitoring performance: If demands exceed resource capacity, performance degrades [11]. There is no doubt that DBF carried a large amount of information, so that instructors can observe and check every action in each fight phase if they wish. But in the real world, such a huge amount of information requires cognitive processing that is far more than an individual's limited capability of attention resources [12]. It is simply not possible to monitor every parameter and trainees' behaviours. Instructors must focus their attention on the elements they perceive to be of high importance at any particular time. For example, during an unstable instrument approach, which exceeds the acceptable standard operating procedure (SOP) parameters, an instructor will be analyzing the glide slope, angle of bank, speed etc., rather than, say, checking if the fuel tanks are equally balanced. At this moment fuel is unlikely to be the important training message and re-prioritization has removed it from the instructor's scan. In phase-3, the integration of eye tracking information helps instructors locate key actions of the trainee pilot rapidly, minimizing cognitive processes, saving their attention resources and thus optimizing the instructor's attention allocation and hence review performance. Furthermore, eye tracking technology can also indicate trainee pilots' attention distribution [13], so that instructors can identify inappropriate scanning (of instruments and external cues) in flight operation. Therefore, instructors assessed that the combination of both DBF and ET data is a powerful training tool for both student pilots and instructors (Figure 5).

4.2 Scanning Pattern during Time-limited Monitoring Process

The results indicate that among three phases, only review performance showed significant difference, while monitoring performance did not show significant differences. It can be attributed to the time limitation for the instructor's monitoring task. The review task allows an instructor to replay videos and check DBF information continuously to obtain the desired information related to operational behaviours of trainee pilots. However, monitoring is strictly time-limited. In time-limited circumstances, the faster the cognitive processing of the task, the better the performance and the faster the processing is completed, the more time is available for subsequent tasks [14]. Due to the complexity of flight operations, instructors have to observe trainee pilots' operational behaviours and thus evaluate their



Figure 5: Eye Tracker can record a pilot's attention distributions, pupil dilation and operational behaviours in the flight deck.

performance simultaneously. According to instructors' monitoring experience, some instructors tend to form a regular scanning pattern only focusing on key operational behaviours that are most error-prone [15]. It is difficult to explain these varying attentions, however, they would suggest that the multiple sources of information that individuals have exposure to other stimulus or flight profiles, training experiences and incidents have mentally primed them differently [16]. They might have developed a pattern for processing information under normal conditions which is then repeated in time pressure situations. Hence, instructor's monitoring performance under a regular scanning pattern will remain unchanged among three stages of experiments.

4.2.1 Instructors may be Subject to Over-confidence. The results of post-hoc pairwise comparison by Bonferroni show that there is no significant difference between the task performance of phase-1 and phase-2. On the contrary, their monitoring performance dropped slightly, but not statistically significantly. It means that even with the exposure to the DBF, instructors were content with their assessment of their ability to spot errors. But this self-confidence is blind and therefore potentially complacent. Overconfidence is more common in experts compared to novices, and can be aggravated with experience accumulated [17]. Instructors with rich and successful flight experience trend to trust in their own judgements rather than check mistakes by other methods. In fact, instructors generally stated that they used the DBF to confirm something already suspected from the simulator sortie or even use data in evidence against a trainee who doubted the errors that they had made. The DBF was not used to systematically review the simulator profile looking for other errors that had not previously been spotted. Moreover, it was also ascertained by instructor's feedback that many of instructors did not routinely use the DBF for their instructional de-brief. A DBF is a rare commodity and the instructors in this study only usually got access to one at Brize Norton. For this reason, they were not well practiced in its functionality and refrained from using it. Others did not consider that the DBF added enough weight to a de-brief to justify its setup and use. Again, because of this view they were not well practiced in its functionality. As it was known that so few instructors use the DBF to augment de-brief, it was necessary to track their evaluation of its worth, both before and after seeing it action. However, most of instructors did feel eye tracker providing sufficient and specific information to assist them on the de-briefing. The overconfidence among instructors is similar to Dunning-Kruger Effect, and could be improved if they are aware of their own limitations in spotting errors and therefore the benefit of eye tracker and de-briefing [18]. Some of instructors admitted that by using eye tracking information they spotted more inappropriate operational behaviours committed by trainee pilots than before. Therefore, those instructors would like to change their approach to monitoring and assessing trainee pilot's performance.

5 CONCLUSION

This research analyses instructors' performance of a monitoring and reviewing task across three phases with different information exposure. Post-DBF without eye tracking exposure provides a high degree of information which may exceed attention capacity, which in turn has a negative impact on the instructor's ability to reviewing trainee performance. Although integrating eye tracking information will also bring instructors additional volume of data, it can facilitate their monitoring performance in terms of significant operational behaviours and in directing instructors' attentions. The integration of an eye tracker into the flight deck simulator may be regarded as a positive instructional tool to improve instructor performance..

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