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The use of artificial intelligence in the learning of flight crew situation awareness in an undergraduate aviation programme

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ABSTRACT: An airline flight crew is said to have situation awareness when they have an accurate interpretation and understanding of the physical and emotional environments in which they find themselves situated. Situation awareness allows the flight crew to evaluate and predict events that occur in the environment in which they are situated and, perhaps, more importantly determine the risks associated with that environment, such that the crew can develop an appropriate course of action to minimise or manage potential risks. This article will discuss an intelligent software agent that will assist in the training and assessment of a trainee pilot's situation awareness through the observation of a physiological cue, in this case a pilot's eye movement. This behaviour will be compared to a gaze database in order to decide whether the pilot is demonstrating appropriate or inappropriate situation awareness. The trainee pilot will be alerted if their behaviour is judged by the agent to be consistent with a loss of situation awareness. This will be used as a training tool for trainee pilots.

INTRODUCTION

An analysis of aviation safety and accident reports indicates that human error is the major contributing cause of aircraft accidents and incidents. It has been argued that at least 70% of all accidents worldwide are caused by inappropriate flight crew actions or in some cases flight crew inactions [1]. The literature also indicates that these flight crew errors were more likely to be unrelated to a flight crew's technical flight proficiency [2]. That is, flight crew errors were more likely to involve deficiencies in the non-technical flight skills area. However, in more recent times anecdotal evidence seems to indicate that flight crew errors in the technical flight skills area are on the increase. This may be due to the shifting of focus away from the learning of technical flight skills to the learning of non-technical flight skills. It could also be due to a lack or loss, of situation awareness (SA) during the decision making process, which led to inappropriate actions or non-actions.

It should be understood that pilots have a thorough understanding of, and proficiency in, both technical and non-technical flight skills and they are frequently assessed for competency in these areas. Technical flight training includes all the skills necessary to physically fly the aircraft, that is, control movement of the aircraft around all three axes of rotation, together with the skills required to manipulate the automated systems. These automated systems include the auto pilot and auto throttle; and the automated engine and cabin monitoring systems that effectively replaced the flight engineer in the cockpit. Non-technical flight training includes all the skills necessary to coordinate the flight crew, assess error, and risk detection and management, and is mediated through dedicated crew resource management (CRM), safety management systems (SMS), and risk and safety management (RSM) courses.

Thatcher has argued before that CRM, SMS, RSM and human factors training would be better learned, and better recalled and implemented during periods of stress or high workload in flight, if they were learned during *ab-initio* flight education and training when the basic technical flight skills were being learned [3][4].

Airline manufacturers have tackled the problem of human error from another direction. They have tried to alleviate the problem of human error by substantially removing the pilot from flying, monitoring and decision making activities, by increasing the level of automation on the aircraft. However, the level of automation and its associated workload have the potential to lead to a loss of SA, which may have an effect on a flight crew's decision making capacity.

Pilots undergo training in loss of SA prevention. But, despite the fact that pilots are highly trained professionals some pilots fail to demonstrate a high level of SA on the flight deck during simulator training. Thatcher et al have suggested an intelligent agent paradigm, which will assist pilots with reducing the manifestations of human error on the flight deck [5]. This has been further developed by Thatcher into a framework for a situation awareness agent [6].

SITUATION AWARENESS

Situational awareness has been defined as *...the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future* [7][8].

Situation awareness has three levels, perception, cognition and application or prediction. That is, elements in the environment must be perceived correctly (perception), once perceived, these elements must be interpreted and understood correctly (cognition) and, once the elements are interpreted and understood correctly, they can be applied to events or they can be used to predict future events (application or prediction). Full (or complete) SA involves these three sequential levels; perception, cognition and prediction. Endsley describes the levels of perception, cognition and prediction as SA level 1, level 2 and level 3 respectively. Endsley has suggested a more complex model of SA and its maintenance and development (see Figure 1) [9][10].

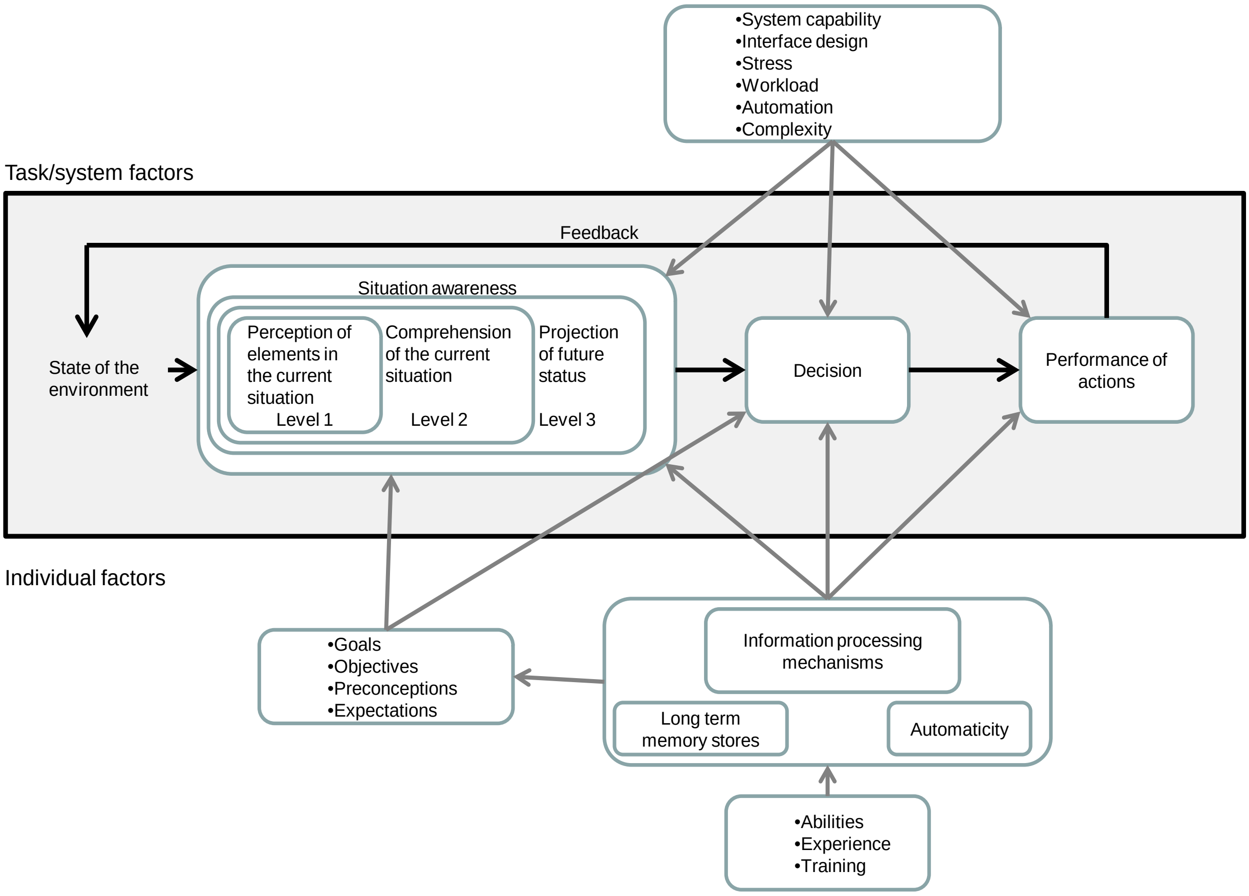

Figure 1: . Situation awareness model (Endsley [10]).

Jones and Endsley have analysed the causes of loss of SA and have found that the vast majority, over three quarters of the total events (76.3%), occurred in level 1 SA; that is, a failure in the perception of elements in the environment [11].

Further analysis has revealed that this failure in correct perception occurred in: 11.6% of cases because the information was not available, 11.6% of cases because the information was too difficult to detect, 8.7% of cases because the perception of the information was corrupted by the pilot's mental model, 11.1% of cases because the information could not be retained in memory because the pilots were distracted or were in a high workload situation and 37.2% because the information was simply not observed because of poor scan technique, attention narrowing or distraction due to workload. The analysis is presented in detail in Table 1. Loss of SA due to incorrect cognition (loss of level 2 SA) occurred in 20.3% of instances and was primarily due to incomplete or incorrect mental model held by the flight crew (see Table 1). Loss of SA due to a failure to predict the correct future action occurred in only 3.4% of instances (see Table 1).

Therefore, a system that would allow trainee pilots to learn SA during simulator sessions, whilst they are learning the basic technical flight skills would be most beneficial to learning and retention of SA skills because the two skill sets would become linked [3]. Assessment of trainee pilot SA, during simulator sessions, that captures and reports errors in SA in real time, during the perception stage (level 1 SA) would help pilots learn when they are losing SA and in what particular situations they have a tendency to lose SA. It would also enable a better understanding of what SA is. This has the potential to help eliminate some three quarters of the loss of SA errors.

Table 1: Situation awareness error taxonomy (source: Jones and Endsley [11]).

Reasons for errors in SA
Loss of Level 1 SA (76.3%) • Information not available (11.6%): due to system and design failures, failure of communication, failure of crew to perform required task • Information difficult to detect (11.6%): poor runway markings, poor lighting, noise in the cockpit • Information not observed (37.2%): omission from scan attention narrowing, task related distractions, workload and other distractions • Misperception of information (8.7%): prior expectations • Memory error (11.1%): distractions and work load
Loss of Level 2 SA (20.3%) • Lack of/incomplete mental model (3.5%): automated systems, unfamiliar airspace • Incorrect mental model (6.4%): mismatching information to expectations of model or model of usual system • Over reliance on default values in the mental model (4.7%): general expectations of system behaviour
Loss of Level 3 SA (3.4%) • Lack of/incomplete mental model (0.4%) • Over projection of current trends (1.1%) • Other (1.9%)

The strategy of training pilots in SA at the early stages of their flight training has merit because there are potential problems in solely relying on automation to eliminate human error. Although automation has proven very effective in decreasing aircraft accidents, there is some evidence that, in terms of SA, automation may introduce new forms of errors on the flight deck, which can lead to a reduction in a flight crew's SA.

Anecdotal evidence gained from recent aircraft accidents suggests that automation may have resulted in one form of human error being replaced with another form of human error. Endsley and Strauch maintain that ...*despite their high reliability, accurate flight path control, and flexible display of critical aircraft related information, automated flight management systems can actually decrease,* a flight crew's ...*awareness of parameters critical to flight path control through out-of-the-loop performance decrements, over-reliance on automation, and poor human monitoring capabilities* [12].

PHYSIOLOGICAL CUES FOR THE ASSESSMENT AND LEARNING OF SITUATION AWARENESS

The AERO Lab has developed a project to investigate whether SA can be assessed and learned using physiological or physical measures. Physical measures refer to aircraft speed, altitude, attitude, heading and other parameters related to aircraft performance. Physiological measures refer to body temperature, heart rate, eye movement, facial expression, etc. Sudden fluctuations in these physiological parameters may indicate changes in a person's psychological state and suggest a pilot is losing SA.

This particular project will investigate the use of physiological parameters, such as brain waves, heart waves, heart rate, body temperature, eye movement, blink rate, etc, to determine loss of SA. But, the majority of the techniques to monitor physiological parameters are somewhat invasive for a pilot in the cockpit and require measuring devices to be attached to a pilot's body. This has the potential to cause significant interference to a pilot during flight operations and as a consequence introduce further forms of human error. Other physiological factors that may be monitored with a somewhat less invasive technique are eye movement, pupil dilation, blink rate, heart rate and facial expression.

Initially, the project will focus on eye movement, in particular, saccades, fixations and pupil dilation. Saccades are quick and jerky movements with rapid shifting from point to point. Fixations are events where gaze becomes steady or fixed for a short period of time [13][14]. Pupil dilation is indicated by a change in pupil intensity, shape and size. Fixations with a longer duration than the standard fixation or pupil dilation, can indicate instability in the psycho-physiological state of the pilot [15][16]. Carpenter and Just studied the correlation between eye fixation and cognitive process. From their study they showed that sequence of fixation, fixation duration and locus are closely related to the cognitive process during a cognitive task [17].

Thatcher, from personal experience and conversations with pilots, has come to the realisation that two potential precursors to the loss of SA are attention focusing and attention blurring [18]. Thatcher has suggested that these two behaviours may be good indicators of loss of SA. When a crew member begins to lose situation awareness they tend to either; concentrate (fixate) on one particular instrument or problem and exclude all other information including communication between other flight crew or they tend to try and scan many more instruments than necessary, including attempting to access as much information as possible. Thatcher refers to this as attention focusing and attention blurring. These terms are similar to Endsley's attention narrowing and attention broadening show in Figures 2 and Figure 3, respectively [18].

To reiterate, for this project, it was decided that physiological parameters including eye fixation duration, fixation *loci* and pupil dilation will be used to determine the state of student SA. A flight simulator and eye tracking device will be used to record sample gaze patterns from trainee pilots.

Figure 2: Attention narrowing (source: Endsley [10]).

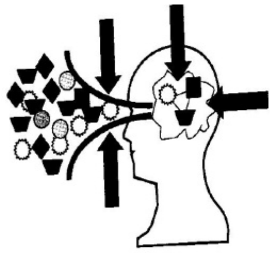

Figure 3: Attention broadening (source: Endsley [10]).

PROJECT DESIGN

A commercially available eye tracker will be used in the project to provide gaze positions. Eye tracker data will be translated into gaze fixation patterns using fixation identification algorithms described by Thatcher and Kilingaru [18]. The following three algorithms will be investigated.

A *Dispersion based algorithm:* which uses a spatial constraint on pilot gaze positions; such that different gaze positions within a proscribed area become part of the same single fixation if the gaze duration is greater than a set time interval (100 - 200 ms) [19].

A *Velocity based algorithm:* which considers the speed at which fixation *loci* change. The velocity is computed by taking the distance between a locus and its neighbour divided by the time difference. Fixations are grouped together based on velocity profile. [20].

A *Hidden Markov model:* which uses a statistical model to determine the most likely hidden sequence of states or features, from the observable data or signal. Features are defined based on specific classification parameters. For example, using the velocity feature, eye gaze events, which have a small velocity have a higher probability of being a fixation event and a lower probability of being a saccade event [20].

It is anticipated that the SA agent will learn to identify pilot eye movement patterns that are consistent with a student losing SA from the comparison of simulator data and knowledge of domain experts. The two basic learning methods for an agent are unsupervised learning and supervised learning.

The SA teaching agent will utilise supervised learning and will use a database of eye gaze patterns, established in consultation with domain experts, to recognise patterns in the input data so as to classify student gaze behaviour as examples of good or poor SA. This will be passed in real time to the trainee pilot to indicate their level of SA. The simulator sessions can also be recorded and the agent feedback can be used as a learning or revision tool.

DISCUSSION AND CONCLUSIONS

It appears that more than 70% of aircraft accidents involve human error as a root cause. A significant number of these accidents are due to a loss of SA. In those accidents that are attributed to a loss of SA some 75% are due to a failure to perceive elements in the environment correctly. This routinely leads to errors in decision making, risk assessment and risk management; culminating in faulty predictions about the aircraft's future position in time and space. Incorrect perception can be due to attention focusing or attention blurring. This can be observed visually in pilots as they lose SA.

Student pilots will tend to scan many more instruments than necessary failing to register the information on critical instruments; or students will fixate on a particular instrument and fail to look at other situation critical instruments. This particular visual behaviour will be picked up by the eye tracker and processed by the SA agent. The agent will, then, classify the behaviour as safe or unsafe and alert the trainee pilot so that they may increase their ability to learn from the situation. The whole process is intended to occur in real time, on-line and be non-intrusive; and provide a SA learning tool that it will be widely accepted by student pilots.

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