SITUATIONAL AWARENESS TRAINING FOR OPERATORS OF UNMANNED AERIAL VEHICLES

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In civilian operations, the utilisation of Unmanned Aerial Vehicles (UAVs) is diverse and the application needs and performance characteristics also vary widely. To this end, the growing opportunities for UAV operations have generated an urgent need for trained operators to ensure these systems are used effectively and safely. This paper discusses the importance and integration of appropriate non-technical skills (NTS) training with a focus on situation awareness (SA) to further improve UAV mission effectiveness. The paper explores technical design and human factors challenges impacting on UAV operations. While technical design solutions to UAV systems and interfaces are examined, the authors contend that specific training strategies, which focus on the human UAV operator, should also be considered.

In recent years, civil UAV application studies have centred on the use of algorithms and unique hardware features that enable the UAV to function independently or perform more efficiently (De la Torre et al., 2016). However, this research frequently fails to stress that there remains a need for substantial human involvement in the operation of UAVs, despite the use of artificial intelligence.

As the ubiquitous use of UAVs continues, transport managers, engineers and UAV operators need to understand the key human factors issues to improve safety, usability, and human operator performance. For example, the optimum blend of automation and human interaction should consider the strengths of humans (e.g., flexibility, and decision making), and strengths of machines (e.g., accuracy, and rapid computation) (Mouloua, Gilson, Daskarolis-Kring, Kring, & Hancock, 2001).

The UAV operator plays an important role in successful UAV missions and further research is needed in the field of human integration into automated UAV systems. Therefore, the aim of this paper is to highlight the importance and integration of adequate training in non-technical skills (NTS) with a focus on situation awareness (SA) in order to further enhance the effectiveness of the UAV mission.

Literature Review

The common cause specified for an aircraft accident is human error.   However, human error is often linked to a latent condition hidden within the entire operation. Such conditions may include high (or low) workload, fatigue, and limited knowledge of the situation or inadequate training. In the study of human factors, it is evident that greater success in efficiency arises when processes and facilities are built to account for people rather than fully exclude humans from the system (Abbott, Slotte, & Stimson, 1996). The benefits and strengths of combining humans and robots to achieve cooperative tasks has become widely acknowledged (Crandall & Cummings, 2007). Manipulating the levels of autonomy of the robot to cater for human input provides a good opportunity to achieve an optimal combination in mixed human/robot teams. At the heart of this assumption is the notion that robot performance is improved with human input (Kaupp & Makerenko, 2008). Thus, if human input is critical to UAV operations, then it is necessary to understand the variables that affect human performance, specifically in tasks where an operator interacts with a UAV.

The study of aviation human factors extends back some seven decades ago. Since then, a large body of theoretical and empirical research has been dedicated to human performance aspects of manned flight.   While this body of research is useful in helping to address some of the impending challenges facing UAV operations, it is apparent that there are major differences between the key human factors issues associated with manned flight and remotely piloted flight. This paper contributes to the UAV body of literature as it attempts to highlight these key differences. It is hoped that it will be instructive and helpful for future UAV policy makers, designers, regulators and training providers to gain an understanding of one of the main non-technical skills training criteria associated with UAV operations.

Methods

While there is much to glean from the perspectives of manned aircraft flight operations, these findings have been considered by the authors in this research with special application to relationship with UAV operations. As such, a narrative literature review has been applied in this part of the study as it provides a valuable theory building technique, and it may also serve functions which assist in hypothesis generation (Baumeister, 1997).

Discussion

The Challenge of Situational Awareness (SA) as a Non-Technical Skill for UAV Operators

Endsley (2000) suggested a definition of SA as "the (1) perception [noticing] of the elements in the environment within a volume of time and space, the (2) comprehension of their meaning, and the (3) projection of their status in the near future" (p. 5). In the design and operation of UAVs, the notion of SA has real implications. In the context of UAVs, SA is broadly defined as the operator's awareness of the status and alterations in a machine's operation (Mouloua, Gilson, Kring, & Hancock, 2001). This awareness should provide the operator with the ability to react quickly and appropriately to unexpected events (Weimer, 1995). High levels of SA will support positive UAV mission performance (Mouloua, Gilson, Kring, et al., 2001) while poor SA is often linked to operator errors (Barnes and Matz (1998).

Themes Relating to Challenges Impacting on Situational Awareness for UAV Operators

Maintaining SA is essential for aviation safety. For the operation of highly autonomous UAVs, there are a number of factors that can collectively be extremely challenging to maintain SA. These factors include:

1. Display design that may not be ideal for maintaining SA.
2. The removal of the pilot from the aircraft, resulting in sensory isolation.
3. Delays in data links, low-grade quality of images from onboard sensors.
4. Lengthy periods of monitoring highly automated systems, leading to the operator feeling 'out of the loop'.

Themes Relating to Training Situation Awareness for UAV Operators

Improved UAV designs targeting flight training are critical processes that help pilots develop their SA capability. Bolstad, Endsley, Costello, and Howell (2010) investigated the effectiveness of six modules of training for developing and maintaining SA by using the general aviation version of the Situation Awareness Global Assessment Technique (SAGAT) installed on a computer located next to the simulator to measure SA. The research revealed that the training modules enhanced the performance of participants on these targeted skills. Results also provided promising support for the effect of the training modules in improving situation awareness.

Sorenson, Stanton, and Banks (2011) compared three theoretical frameworks covering psychology, engineering and systems ergonomics for further understanding and improving pilot SA. Although engineering and psychology provide considerable knowledge of our understanding of SA, the relationship between the individual, the artefact and the context in

which they work is rarely considered by both disciplines. However, the systems ergonomics perspective offers a more holistic framework to investigate SA by exploring the complex interaction between the individual operator, the artefact and their environment. Matthews, Eid, Johnsen, and Boe (2011) also explored SA assessment utilizing an observer and self-rating methods under highly stressful and challenging training conditions. The findings revealed that subjective SA measures would not likely produce defensible estimates of SA in extreme conditions. Another study found that following a malfunction in a flight simulator, the eye movements of an experienced pilot significantly differed from a novice pilot, suggesting a different disruption to SA (van de Merwe, van Dijk, & Zon, 2012).

Throughout a mission, a pilot often alters their levels of supervisory control between a full auto pilot and other modes. This process of alternation is also common in a UAV operating environment, and depends greatly on the level of autonomy and supervision required in various stages of flight. These transitions will involve some risks and potential reduction in flight performance or an unacceptable change in workload or SA (Nguyen, Lim, Duy Nguyen, Gordon-Brown, & Nahavandi, 2018). Hainley, Duda, Oman, and Natapoff (2013) examined a pilot's efficiency, SA and work load over a number of automation mode transitions, in an attempt to establish objective measurements of gracefulness during mode transition. The experiments demonstrated that mental workload increases, and SA decrease in a monotonic fashion, with relation to the number of manual control loops the pilot is required to close as a result of the flight mode transition. The research also highlighted the reduced attention of the pilot to fuel status, terrain and altitude during times of high workload due to the attentional demands of manual control tasks.

Cuevas and Aguiar (2017) evaluated a behavioural measure to assess SA and understand how specific operator characteristics (knowledge, skills, and abilities (KSAs)) impact on the success of the mission in UAV operations. The results revealed that participants with greater manned flight experience performed better with respect to SA elements because, as expected, pilots of manned aircraft typically undergo rigorous CRM and/or human factors training throughout their flight training (Cuevas & Aguiar, 2017). The study also demonstrated a statistically significant positive correlation between gaming experience with First-Person Shooter (FPS) games and indicators for spatial orientation (Cuevas & Aguiar, 2017). The researchers explain that this finding is most likely due to the need for spatial awareness in these kinds of games where the player is an avatar in a virtual world. For the player to succeed, they must possess the skill to receive and comprehend all the available information to correctly assess their situation (Cuevas & Aguiar, 2017).

Although a significant proportion of these studies investigated manned flight operations, there are very few studies that investigate effective assessment and training programs to strengthen SA in UAV operations. Yet, many of the findings are relevant to UAV operations

and provide a solid platform from which appropriate UAV operator training programs to enhance the non-technical skill of SA may be constructed. Perhaps the most striking findings, that best inform improvements to SA training for UAV operators are summarised below:

- UAV operators with greater manned flight experience performed better with respect to SA elements (Cuevas & Aguiar, 2017).
- UAV operators with gaming experience associated with First Person Shooter games showed improved performance in spatial orientation (Cuevas & Aguiar, 2017).
- UAV operators trained to effectively manage workload in highly stressful flight situations are likely to demonstrate positive skills of social cognition (social SA).
- UAV operator training needs to include pilot appreciation of the increased risk associated with transitions and changes in automation modes depending on the stages of flight. Such transitions will involve some risks and potential reduction in flight performance or an unacceptable change in workload or SA (Nguyen et al., 2018). As such, UAV operators need to be provided with guidance and procedures to assist in SA management during transitions.

Conclusion

The advent and growth of UAV operations has underscored the critical need for trained operators to ensure these systems are used effectively and safely. We have explored the technical design and human factors challenges impacting on UAV operations. Technological solutions to improving SA for UAV operators include consideration of: the principles of UAV display; the removal of the pilot from the aircraft resulting in sensory isolation; data links and sensor imagery; lengthy periods of monitoring highly automated systems which lead to the operator feeling 'out of the loop'. However, the paper also highlighted important considerations to inform improvements to training SA in UAV operators including: UAV operators with greater manned flight experience perform better with respect to SA elements; UAV operators with gaming experience show improvements in spatial orientation; procedures and the design of systems should consider supporting crew to better manage workload during stressful events; and UAV operator training should include pilot appreciation of increased risk associated with transitions in automation levels.

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