WORKLOAD, SITUATION AWARENESS, AND TEAMING ISSUES FOR UAV/UCAV OPERATIONS

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A new partnership is forming between humans and uninhabited aircraft. To augment the abilities of military forces on the ground and in the air, the US Armed Forces have developed several Unmanned Aerial Vehicles (UAVs) to work in conjunction with human pilots and enhance surveillance and combat capabilities. Even with no onboard pilot, unmanned aerial vehicles (UAVs) and combat-tailored versions (UCAVs) rely on proficient human operators on the ground for proper guidance and munitions deployment. For this reason, system designers must consider several key human factors issues in the development of functional UAV/UCAV systems. This work addresses three of these issues: workload, situation awareness, and teaming concerns. Recommendations to maximize operator efficacy, based on findings from human factors and ergonomics research, are presented as well as implications for training.

INTRODUCTION

Recent US military operations in the Persian Gulf employed Tomahawk cruise missiles, fired from ships in the region, to eliminate enemy air-defense systems and pave the way for piloted aircraft. For the most part, these efforts were successful. However, due to their limited flexibility, cruise missiles often miss their targets, or fail to update trajectories in time to counter the movement of targets after launch (Iannotta, 2001). To improve on this capability, the armed forces expanded development of uninhabited aircraft, or Unmanned Aerial Vehicles (UAVs), to perform reconnaissance and surveillance missions, and combat-modified UAVs (UCAVs) to deliver weapons to enemy targets (Howard, Bray, & Lyons, 1996; McDaid & Oliver, 1997). The goal of these UAV/UCAV programs was to augment human forces, both on the ground and in the air, by generating battle space data and clearing the way for human piloted aircraft in dangerous settings.

As UAV/UCAV systems evolve in coming decades, program managers and engineers must consider several key human factors issues in order to improve safety, usability, and human operator performance. For example, the optimal mixture of manual and automated vehicle control should take into account the strength*s* of humans (e.g., flexibility, decision making) and machines (e.g., accuracy, quick computations), and minimize their weaknesses (see Mouloua, Gilson, Daskarolis-Kring, Kring, & Hancock, 2001).

To aid in this endeavor, we focused on three primary areas with significant importance to overall UAV/UCAV mission effectiveness: workload, situation awareness, and teaming issues.

The following sections outline design recommendations regarding these areas based on empirical and theoretical literature and a task analysis of typical UCAV missions. In addition, exemplar solutions to reduce the impact of instances such as high workload, reduced situation awareness, and teaming conflicts are offered.

FINDINGS

Physical and Cognitive Workload

The complexity of UAV/UCAV systems, as well as mission demands on the operator, indicate that the problem of mental workload deserves critical attention in the design of interfaces, displays, and how control stations are staffed. The concept of workload can be defined as the combination of task demands, or load factors, and an operator's response to those demands. For instance, common load factors in Air Traffic Control (ATC) include the number of aircraft handled by the controller, sector flight time, sector area, and aircraft speed and separation. Each controller's response to the load incorporates his or her own skill level, experience, and the use of various adaptive strategies such as reducing time spent on less important peripheral tasks, increasing aircraft spacing, and stacking planes in the sector. Svensson, Angelborg-Thanderz, Sjoeberg, and Olsson (1997), for example, evaluated aviation pilots and showed that as task complexity increased in a series of simulated flights, heart rate and pilots' subjective assessment of mental workload also increased.

When an operator uses a highly automated system, there may be long periods of free time and this may induce a vigilance based stress (see Hancock & Warm, 1989). Further, interpolated in such intervals, there will be periods of high mental workload in short bursts, such as during malfunctions (see Huey & Wickens, 1993). A principal source of high workload is time pressure associated with a task, particularly in situations requiring the completion of multiple tasks within a fixed time span. In aviation, for example, a majority of a pilot's work in an automated cockpit is scheduling. Communications, navigation, systems monitoring, decisions, manual programming, and other tasks that must be processed and completed within an appropriate time frame. As time pressure increases, workload also increases.

Although the negative effects of high workload have been well documented and makes intuitive sense, low workload can be equally as damaging to performance. For example, in highly automated systems, a large portion of the operator's task load is supervisory in nature, monitoring system parameters and maintaining alertness for malfunctions. Tasks may include visual scanning of status indicators, running computer-assisted diagnostics, or making subtle changes in the system's ultimate goal or purpose. These tasks, which require sustained attention from the operator, can become repetitious and dull over time and can lead to degraded performance and operational errors (Hancock & Warm, 1989).

Research on sustained attention, or vigilance, dates back to the second World War when the Royal Air Force sought to explain why their radar operators were failing to notice targets after only short periods on duty (Davies & Parasuraman, 1982; Mackworth, 1948). Subsequent studies revealed that in tasks of sustained attention, performance declined as early as 20 min into the task and continued to decline the longer one performed the task, a phenomenon termed the "vigilance decrement." Any time persons are required to monitor and attend to a large number of events, such as in air traffic control, nuclear power plant operations, airport security, or presumably supervisory control of UCAVs, vigilance will be a factor in performance. Therefore, it is important to consider both ends of the spectrum, from high workload to low workload in developing effective interface and controls for UCAV operation.

For UCAV operators, the most effective interface and control system should allow for an optimal balance between the operator's resources and the demands of UCAV operational tasks. Typically, systems fall somewhere in between the two extremes of manual control to complete automated control of all functions. For example, power assisted steering, anti-skid braking, and speed controls all help drivers maintain assisted control, while other functions such as engine cooling, oil pressure, even lights and locks are left to automation. In a similar fashion, UCAV operations should utilize a combination of manual control and automation to best manage workload and vigilance.

In full manual control, UCAV operators would be responsible for all system functions during the mission. Flight attitude and speed, navigation, obstruction and threat avoidance, target search and recognition, munitions selection and deployment, and other flight duties (normal and abnormal) all would require hands-on manipulation of controls. By contrast, full automation of system functions may prohibit the operator from controlling these tasks. Many of today's cruise missiles use full automation, once launched, they can be destroyed but cannot be recalled or redirected. The middle ground, supervisory management, allows operators to handle higher-order tasks, such as target recognition and munitions deployment while lower order functions (flight control, obstacle avoidance, area searches, etc.) can be controlled by automation. This arrangement frees the operators from performing mundane flight tasks and focuses attention on mission accomplishment.

Furthermore, on-board flight automation, automatic target recognition systems, and alerts should require operator action only on an as needed basis. Productivity, next to safety, is a prominent concern for UCAV designers. If the ratio of working vehicles is high compared to the number of operators involved, costly and resource intensive areas of personnel and training will be reduced. Design of a practical interface and control system for the operation of UCAVs must consider workload and vigilance factors. Systems that combine manual control with automation to provide operators with supervisory management capabilities appear to offer the best opportunity to reduce the deleterious effects of both high workload and loss of vigilance.

Situation Awareness and Assessment

The concept of situation awareness also has direct implications in the design and control of UCAVs. Although definitions vary, situation awareness is generally described as the operator's awareness of the status and changes in a machine's operation. This awareness should allow the operator to react appropriately and quickly to unexpected events (Weimer, 1995). In the context of complex UCAV systems, a high level of situation awareness will be necessary for enhanced mission performance.

A recent study by Barnes and Matz (1998) indicated that poor situation awareness was related to operator errors in a series of simulated UCAV missions. For instances in which the UCAV crashed, a narrowed attentional focus, especially during targeting activities, was partly responsible for the crashes.

Exemplar solutions to similar problems might include furnishing operators with the capability to visualize or conceptualize the system and environment at several levels. For instance, for awareness inside and outside the UCAV, window screens that indicate the underlying processes controlled by automation will allow operators to see and understand what the automation is doing and why. As indicated by Rasmussen (1986), support systems for machines should make the deep relational structure of the system environment visible to operators and help to identify options for action and indicate the boundaries for successful performance. Such a design will decrease automation surprises, and enable the operator to maintain a broader picture of the overall system.

Furthermore, UCAVs can provide ground operators with inherent situation awareness that has the potential to be extraordinary. By virtue of UCAVs available communications links to the ground and other UCAVs, operators literally have at their fingertips data streams and views never before available in the cockpit. In addition to conventional inside-out view through on-board sensors and cameras, off-board sensors of the target and outside views of the operator's UCAV are available from other UCAVs. Additionally, more encompassing views are available from other airborne assets, such as Joint STARS (Surveillance & Target Attack Radar System), AWACS (Airborne Warning & Control System), and higher yet perspectives from overhead satellites.

Teaming

The manner in which personnel on the ground control UCAV systems should also be examined. A single UCAV operator might work in conjunction with command personnel, aircraft pilots, and other UCAV operators. In contrast, a team of operators, analogous to an airplane crew, may be necessary to control each UCAV effectively. Barnes and Matz (1998), for instance, have argued against single operator UAV teaming based on comparisons of single versus two-person crews in a series of simulated missions.

Additional research is therefore needed to determine the optimal UCAV crew size, and issues related to teamwork. To ensure effective mission performance, various team members must collaborate on a common goal with minimal conflict and confusion. One potential source of misunderstanding is the massive amount of UCAV downlinked information available to all personnel via parallel networking. Operators will want to use what they know. Valuable information, when accessible, will naturally be shared and used. The key is to use this information efficiently among people for mission accomplishment.

Possible solutions include providing humans with final authority/capability for ultimate UCAV override of an attack and creating a mechanism for communicating understanding the near real-time situation at a higher level across several connected teams or individuals. Consideration should be given to the creation of specialty teams to intervene and handle emergencies and to make provisions for estimating the confidence levels in the quality of the information represented presented to the controlling authority.

Given the unprecedented access to information necessary to control UCAVs, a logical question to raise is, if operators themselves will be authorized to authenticate targets and trigger the unleashing of lethal force, similar to the pilot's authority now afforded by the rules of engagement. Currently, combat pilots have this authority, in part, because the flight crew is in the best position to assess the situation. With UCAVs, communications are a necessity and other team members possessing high levels of technical or combat expertise could be called upon for assistance. With easy access to the same information as the operator, mission performance could be enhanced with the help of target detection specialists or perhaps with experienced commanders. These other people could act as team members with the operator, in tandem or in parallel, to add assessment capabilities or to provide the final authority to attack a certain target. Clearly, with teams connected together via an Intranet and to resources around the world, the new avenues for decisions and possibilities for combat tactics will open up and must be thought through.

Other UCAV team opportunities arise when abnormal situations occur. For example, rather than training all operators to handle emergencies, specialty teams could step in, even from remote locations, to take over the vehicle from normal operators to troubleshoot and control malfunctions to aid battle damaged vehicles, or to counter unexpected enemy tactics. This would not only relieve the operator from nursing an ailing UCAV while trying to operate healthy vehicles, but would focus specialized expertise when and where it matters, to save the vehicle or at least to minimize damage and exposure. Such teams also could be provide with specialized troubleshooting equipment normally unavailable to operators allowing them to project "what if' solutions using predictive simulation.

SUMMARY

UCAVs offer a viable alternative to placing human life at unnecessary risk in combat situations. However, reliable use of UCAVs in future military operations depends on effective system designs that are grounded in sound human factors research and principles. Consideration of the impact of workload, situation awareness, and teaming issues in the UAV/UCAV context will aid the design process of these systems and help to ensure enhanced mission performance.

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