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Effect of time pressure and target uncertainty on human operator performance and workload for autonomous unmanned aerial system

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ABSTRACT

Autonomous unmanned aircraft systems (UAS) are being utilized at an increasing rate for a number of military applications. The role of a human operator differs from that of a pilot in a manned aircraft, and this new role creates a need for a shift in interface and task design in order to take advantage of the full potential of these systems. This study examined the effects of time pressure and target uncertainty on autonomous unmanned aerial vehicle operator task performance and workload. A 2 × 2 within subjects experiment design was conducted using Multi-Modal Immersive Intelligent Interface for Remote Operation (MIIIRO) software. The primary task was image identification, and secondary tasks consisted of responding to events encountered in typical UAS operations. Time pressure was found to produce a significant difference in subjective workload ratings as well as secondary task performance scores, while target uncertainty was found to produce a significant difference in the primary task performance scores. Interaction effects were also found for primary tasks and two of the secondary tasks. This study has contributed to the knowledge of UAS operation, and the factors which may influence performance and workload within the UAS operator. Performance and workload effects were shown to be elicited by time pressure. Relevance to industry: The research findings from this study will help the UAS community in designing human computer interface and enable appropriate business decisions for staffing and training, to improve system performance and reduce the workload.

1. Introduction

The roles of unmanned aircraft systems (UASs) have expanded greatly within the military in the last few years, and every branch of the U.S. military now employs their own form of a UAS in their intelligence, surveillance, and reconnaissance operations (Cooke, 2006). UASs have played a major role in both Operation Iraqi Freedom and Operation Enduring Freedom, and have done so without putting American pilots' lives in danger (Scarborough, 2003; Guidry and Wills, 2004). With the rapid growth of the application of UAS application and increasing levels of complexity, there are many new challenges for such systems to complete the missions in an efficient manner, especially when there are high time pressure and uncertainty involved in the mission. This study is trying to address the effect of time pressure and uncertainty on UASs mission performance from a human factors perspective.

Specific human factors issues associated with UASs involve the fact that the human operator has a significantly different role than a pilot in a manned aircraft. This new role requires a shift not only in personnel selected for the job, but the training involved, and an interface design which allows for the optimal cooperation between human and automation in order to achieve the full potential of the system as a whole (Nelson and Bolia, 2006). The crucial issue in implementing state of the art technologies, such as UASs, is not one of hardware creation, but of the assimilation of sensory inputs, the processing of information pertinent to user goals, and translation of the user's decisions into subsequent actions (Oron-Gilad et al., 2006). Research on UASs has opened up new areas of interest, which requires a whole new way of thinking about the implementation of automation and related issues and how they affect the operator. The operator of a UAS must be able to monitor not only the state of the aircraft, but that of the aircraft's environment, as well as the missions that the aircraft is carrying out. This heightens

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the cognitive demand placed on the operator, and effects on workload are expected (Liu et al., 2009; Liu et al., 2011).

One of the main roles of UASs in military use today is target acquisition. Target acquisition is a challenge, even with the technology currently in use. This is due to low fidelity imaging, inaccuracy of automation in target detection, and uncertainty associated with images (McCarley and Wickens, 2005). This, in turn, requires the human operator to expend some level of cognitive resources in order to solve them and accurately designate enemy targets. One of the important factors involved in target acquisition task is time pressure effects on the workload of the operator, and any performance detriments they may cause. Current levels of automation can assist the human operator with many tasks, but when the operator's workload is already high, the assistance of a decision aid, and the time pressure it is associated with, may further increase workload. The relationship between time pressure, workload, and automation is a complex one that has proven difficult to study. Research conducted on UAS operation found that participants rarely utilized the automation, even when time pressure was added and workload was increased (Ruff et al., 2004). The effects of time pressures have been addressed in human factors literature, including the effects on performance and workload (Hughes and Babski-Reeves, 2005; Svenson, 1997; Burke et al., 2007; Glade, 2000), and the effect with the assistance of decision aids (Sarter et al., 2001; Hailston and Davis, 2006), however, there is very limited research existing for the specific effect of time pressure on UASs.

The fact that human operators are physically separated from the aircraft in a UAS, can cause a problem referred to as out of the loop unfamiliarity; in which the operator lacks adequate levels of situation awareness needed to operate a UAS efficiently (Wickens, 1992; McCarley and Wickens, 2005). The unfamiliarity experienced by operators is a result of not only lack of visual cues, but those from other sensory inputs as well. McCarley and Wickens (2005) studied some of the effects of removing the pilot from the aircraft, and termed this lack of sensory inputs “sensory isolation”. The result of sensory isolation showed high levels of boredom, decreased recognition performance, and degraded target detection (Tvaryanas et al., 2006). The identification of targets is particularly difficult due to the low fidelity and restricted visual angle available to UAS operators, and this is made even more complicated when the target lies amidst an array of distracting information, causing uncertainty for the operators. Uncertainty describes the condition an observer experiences when viewing an image which contains confusing distracter items (Vierck and Miller, 2007). When there is a high level of uncertainty in the decision making process, humans will actively search out ways to reduce that uncertainty by gathering more information, and when all else fails, simply suppress the uncertainty and take action (Lipshitz, 1997).

The highly autonomous nature of UASs has advanced the debate about the interaction between humans and automation. The environment in which they operate, and the ability of a human operator to understand and control a UAS within that environment, introduce significant human factors problems. The history of UASs demonstrates the industry's focus on developing the technology around task capabilities, with little thought for how the new technology affects the human operator. The reliance on automation to solve human factor issues which arise has caused a drastic change in the role of a human in the system, and little research to support the new role.

One area of limitation humans experience during the control of a UAS is workload, which can range from being excessive enough to cause performance detriments, to being too low to maintain vigilance. These workload effects are difficult to anticipate, particularly with new technology such as an interface which allows the control of multiple UASs. In a command and control environment such as UAS, workload, especially cognitive processing related load can impact the performance and situational awareness (Funke and Galster, 2009). What is not known is how different tasks associated with UAS operation affect workload, and may potentially deteriorate performance. The workload is further heightened by the time pressure associated with typical UAS missions with task uncertainties. Automation can relieve some of that workload by identifying the targets and making suggestions to the operator, but automation can be inaccurate in doing so. The human operator must retain supervisory control over the entire system, and therefore must be able to verify any target identification before allowing the automation to execute any tasks. The relationship among these factors that are mentioned above was not well understood for the UASs operations. This study is intended to investigate the effect of time pressure and target uncertainty on operator performance and workload while operating a fully autonomous unmanned aerial vehicle.

2. Methods

2.1. Participants

Thirty participants from Embry-Riddle Aeronautical University (ERAU) were recruited to participate in the study. Participants were offered extra credit in an undergraduate course in exchange for their participation. Among the thirty participants, 10 of them were female. The average age was 20.4 with a standard deviation of 1.003. An informed consent form was given to all participants to review and sign prior to the start of the experiments.

2.2. Apparatus

The apparatus consisted of a standard computer running a UAS software test bed simulation device called MIIIRO (Multi-modal Immersive Intelligent Interface for Remote Operations). The MIIIRO test bed has been previously utilized as a UAS simulator (Nelson et al., 2004; Tso et al., 2003). The setup included two monitors, the primary of which portrayed the Tactical Situation Display (TSD). The TSD included a topographical image of the operating environment, highlighted routes including waypoints, critical targets, other intruding aircraft, and the Mission Mode Indicators (MMI). The secondary monitor displayed the Image Management Display (IMD) which includes an image cue and image display used for target acquisition. Fig. 1 shows the MIIIRO interface.

2.3. Design

A 2x2 within subjects, fully factorial design was used for the study. The independent variables were target uncertainty and time pressure. Target uncertainty consisted of high uncertainty images, those with an equal number of distracters similar to the target, causing an equal chance of missing or hitting the target, and low uncertainty images which contained either all targets or all distracters. A management by exception (MBC) strategy was utilized to create time pressure for the primary task. Under MBC strategy, MIIIRO automatically processed the image after a specified time limit unless the operator vetoed within that time limit. The time pressure consisted of either three or six second time limits during the target acquisition task. From previous studies (Liu et al., 2009) it was determined that a three second time limit would provide adequate time pressure, while a six second time limit was long enough to provide little to no time pressure. Dependent measures were workload collected by NASA-TLX, image processing time and