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UAVs as Tactical Wingmen: Control Methods and Pilots' Perceptions

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Introduction

A fundamental question that must be addressed when developing an automated system that executes human intentions is who (the human or the computer) is in control and under what conditions? Recent research examining human performance in the remote control of UAVs demonstrated that the management-by-consent control strategies, in which actions suggested by automation are approved by a human, produce superior performance as opposed to management-by-exception, in which actions are performed by automation unless a human intervenes[1]. Allowing a human to retain ultimate authority and control in directing UAVs from a remote ground site provides improved human performance as well as increased situation awareness.

While much progress has been made to improve human-in-the-loop performance for remote control of UAVs from ground stations, research into remote control of UAVs from tactical aircraft is in evolutionary stages. One future remote control application of UAVs could be the assignment of UAVs as "wingmen" in a tactical air formation led by a single, manned aircraft for offensive missions. Preliminary research suggests that without higher levels of autonomy and a shift from management-by-consent to management-by-exception control strategies, the workload of pilots controlling UAVs in-flight, especially single seat pilots, will be too high[2].

While previous research in abstract settings can inform the design of a UAVs-as-wingmen system, before more significant research and development is invested in this design problem, a critical step that should not be overlooked is the involvement of the military pilot community for their input. It has been well-established that to design a successful complex sociotechnical system such as those found in command and control settings, a user-centered design approach is needed in which end-users, or stakeholders, have a role in shaping a final design[3]. Because tactical aviation is the quintessential complex sociotechnical system in which automated systems support human intentions, pilots' perceptions and attitudes are equally as important as technological constraints. In an attempt to involve the pilot stakeholder group in the design of a UAVs-as-wingmen system, a recent experiment was conducted through the MIT Aeronautics and Astronautics department with Air Force and Air National Guard pilots to assess both general attitudes towards UAVs as well as how they think autonomy should or should not be used.

The Experiment

The display in Figure 1 represents the interactive rapid prototype display designed to investigate three main issues: 1) What levels of pilot control and UAV/human interaction do pilots think are appropriate, 2) What is the relative importance of different display characteristics, and 3) What role did pilots view UAVs as "wingmen"? This display includes a combined navigation and flight overview. The white triangle at the bottom of this screen represents the manned aircraft controlling the UAVs and the green triangles represent the individual UAVs with their corresponding position numbers in formation behind the manned aircraft, as well as their current location in relation to navigation aids. In this experiment, the overview display was occasionally replaced with simulated uploaded visual imagery, mimicking both pre and post weapons release imagery. In addition, individual UAV status displays were included to provide the pilot with immediate "wingmen" status.

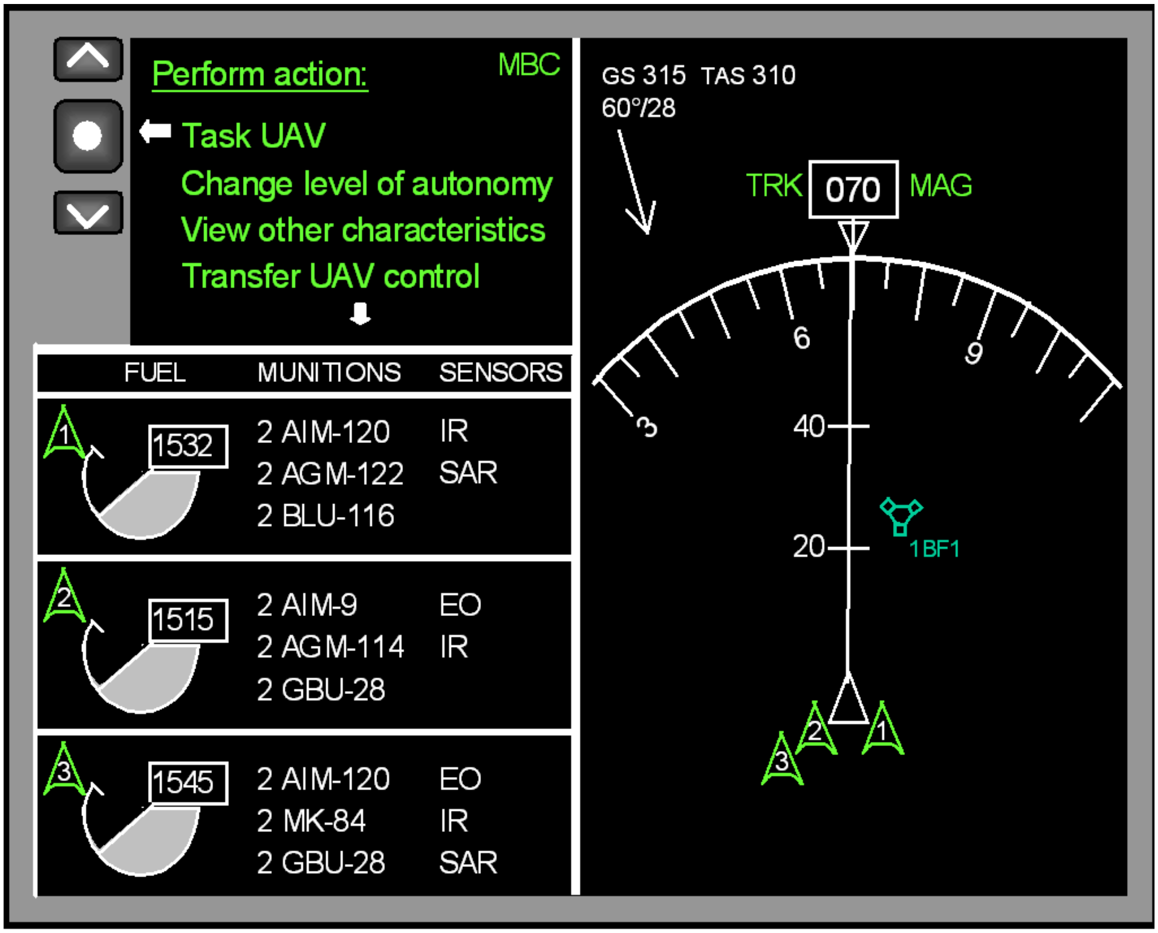

Figure 1: Mock Manned Cockpit UAV Control Panel

The most important part of the display is the message/command window, located in the upper left side. The push buttons on the left allow the pilot to scroll through various options. For example, the pilot could change UAV flight characteristics, such as the altitude or speed of the UAVs, as well as command the UAVs to prosecute targets. It was through this interactive display element that different control strategies were introduced. The display is not meant to be a high-fidelity prototype; rather, it exemplifies general display elements that allow pilots to explore a possible control methodology in order to generate feedback for the development of future system requirements.

The cognitive walkthrough methodology, in which users perform tasks through exploration and interaction with an interface, was selected as the experimental tool for several reasons. As an interface usability inspection tool, the cognitive walkthrough engages relevant stakeholders to not only determine any potential usability problems, but also allows designers insight into the user's problem solving processes[4]. It is an informal and relatively cost effective procedure that produces tangible results, especially if conducted early in the design process. While originally designed for the office environment, it has been successfully applied to cockpit avionics interfaces, and in this setting, is known as the Cockpit Cognitive Walkthrough[5].

The pilots who participated in this study included four A-10 pilots, two F-16 pilots, two crewmembers in a multi-crew AC-130 cockpit, and two ground pilots of the Predator UAV. Unfortunately, a larger or more representative sampling of military pilots could not be gathered due to wartime deployments and operational considerations. The average age of the pilots was 39 with an average time in service of 18 years. In the experiments, pilots were given several minutes to initially familiarize themselves with the displays before the formal cognitive walkthrough. The scenarios in which the pilots interacted with the displays included target acquisition, UAV assignments, and battle damage assessment, to include secondary strikes. In addition, pilots were asked several general questions about the display design, their confidence in flying with UAVs, and what levels of control they thought were most appropriate for various scenarios.

Scenario Analyses

Overall, the pilots agreed that the management-by-consent level of automation was appropriate in most situations. However, pilots asserted that in certain situations, UAVs should have complete autonomy. For example, if the UAV was being fired upon, it should be allowed to defend itself as necessary. Conversely, if the UAV was firing at enemy positions along the forward line of troops, then it should be monitored closely and controlled very tightly.

When asked about target identification and assessment, pilots asserted that the UAV should make a recommendation that the pilot could accept, reject, or change, but never be allowed to automatically designate a target. They believed that in the "free-flowing environment" of an offensive combat mission, only a human being with experience and knowledge could accurately assess the situation and determine a course of action. Target selection depends on previous intelligence reports, briefings, and orders from a command center. In addition, pilots did not think that a group of UAVs should self-select which UAV was the best candidate for a mission. Despite the increased workload that UAV selection would impose, pilots generally thought the UAVs could not make informed decisions about both their individual states and how their capabilities served the current mission.

Pilots were roughly divided on whether or not it was necessary for a UAV to seek approval to leave the formation after already having been selected to accomplish a particular mission. The pilots of the fighter aircraft with more experience flying in and leading formations generally thought that the UAV needed to ask permission before leaving the formation on an assigned mission. They described how a formation acts as a "cohesive unit," how each pilot depends on the others in the formation for mutual support, and that as a result, the UAV should provide "specific information to maintain deconfliction". In contrast, pilots who worked in multi-crew cockpits or controlled UAVs generally thought that the UAV should just leave the formation on its own without asking for permission once assigned a mission. In general, this second group of pilots believed that continuously granting permission to the UAVs for "trivial" tasks would be tedious and unnecessarily increase the workload.

Every pilot agreed that UAVs should automatically obtain imagery of targets and upload that imagery to the manned aircraft. However, they suggested the inclusion of an audiovisual cue to alert them when the image is ready to be displayed. This cue would allow pilots to finish other tasks before replacing the current screen with the target image. However, pilots did not think UAVs should perform any kind of battle damage assessment. Finally, the pilots believed that the UAV should await orders after performing a mission. The lead pilot should decide to allow the UAV to return to the formation if it still had fuel and munitions, or allow it to return to base if it was no longer useful. In either case, the pilots wanted to examine the "flow of the battlefield" to determine how best to proceed.

One futuristic scenario that pilots were presented with was that of UAV communications, both input and output, through Direct Voice Input (DVI). When asked about DVI, the pilots thought it would be unreasonable that a UAV could ever process the slang that is typically spoken between pilots. Additionally, the pilots thought that a UAV could never perform "talk back" to the point that it seemed like just another wingman. In addition, UAVs would not understand hand signals and other similar techniques to communicate that pilots often employ.

Every pilot agreed that it would be impossible to monitor UAV displays similar to the one in Figure 1 in the cockpit of a single-seat airplane. The additional tasks of flying one's own plane, maintaining position, communicating over the radio, and possibly engaging the enemy would be "overwhelming," in the words of one pilot. However, most agreed that a person sitting in the back of a dual-seat aircraft or a crewmember in a multi-crew aircraft would be able to handle the duties of monitoring the extra display and controlling the UAVs. Some pilots felt that controlling three UAVs might be too excessive and that one person might only be able to control one or two of them at a time. Nonetheless, most of the pilots thought that giving control of UAVs to someone flying in the same area was an excellent idea. They agreed that it would reduce the data transit time and vulnerability and that it would be helpful to have a human being in the area of UAV operations to report back on exactly what the UAVs were doing.

General Trends

Because the number of pilots interviewed was small, it is difficult to theorize about the general pilot population. However, some facts quickly become apparent after evaluating the interviews. Both pilots in multi-crew aircraft and both pilots of the UAVs in this study seemed slightly more accepting of a UAV role in offensive combat missions than the fighter pilots. Conversely, the fighter pilots were more hesitant to accept a role for UAVs in offensive combat operations, believing that a UAV could never replace a wingman. One particular A-10 pilot described his relationship with his wingmen as one of trust and loyalty. They trained together, they worked together, and they fought together, and thus a UAV could never replace a human wingman.

When asked what missions were most appropriate for UAVs in general, pilots felt that they should primarily be used for ISR as well as SEAD missions. Missions unsuitable for UAVs included close air support, search and rescue, and most other missions. Even a mission to strike a pre-planned target was deemed too complicated for a UAV to perform autonomously due to the uncertainties that may arise between the time the UAV is launched and the time it arrives in the target area, as well as the uncertainty surrounding positive target identification. Furthermore, most pilots did not want the UAVs operating anywhere near friendly forces on the ground. Whereas the pilots of the UAVs were more inclined to accept a combat UAV role, two fighter pilots asserted that UAVs should not operate in the same airspace with tactical manned aircraft. One pilot was involved in a training exercise at a test range in Nevada during which a software malfunction on a nearby Predator caused it to drift into the path of a group of fighters, resulting in a near mid-air collision.

Conclusion

Advocating the management-by-consent control strategy, pilots commanding UAVs as wingmen would like the automated system to recommend options but they also want the ability to make the final decision themselves. Pilots do not want to make "trivial" decisions, and recognize that some functions should be automated but they want to be kept "in the loop" on most decisions. Some functions, such as acquiring an image or maintaining flight, should be automated whereas others, such as weapons release, should not be automated. However, as demonstrated by this study, not all pilots welcome the addition of UAVs to the tactical manned aircraft arena and these results suggest a complex socio-technical cultural component of single-seat versus multi-crew cockpits could have a significant impact on the acceptance of this technology. The results of this study can only be considered preliminary, however, they suggest that a more detailed study with a much larger and more representative group of subjects could provide a coherent framework through which the integration of manned and unmanned systems in offensive combat missions could take place.

References

[1] Ruff, H. A., Narayanan, S., and Draper, M. H., Human Interaction with Levels of Automation and Decision-Aid Fidelity in the Supervisory Control of Multiple Simulated Unmanned Air Vehicles, *Presence*, 11, 2002, 335-351.

[2] Howitt, S. L. and Richards, D., The Human Machine Interface for Airborne Control of UAVs, Series "The Human Machine Interface for Airborne Control of UAVs" *2nd AIAA Unmanned Systems, Technologies, and Operations*, San Diego, CA, 2003.

[3] Abras, C., Maloney-Krichmar, D., and Preece, J., User-Centered Design, in Encyclopedia of Human-Computer Interaction, W. Bainbridge Eds., Sage Publications Thousand Oaks, 2004

[4] Wharton, C., Rieman, J., Lewis, C., and Polson, P., The Cognitive Walkthrough Method: A Practitioner's Guide, in Usability Inspection Methods, R. Mack Eds., John Wiley & Sons New York, 1994
[5] Polson, P. and Smith, N., The cockpit cognitive walkthrough, Series "The cockpit cognitive walkthrough" *10th Symposium on Aviation Psychology*, Columbus, OH, 1999. 427-432.