

TARGET IDENTIFICATION SUPPORT AND LOCATION SUPPORT AMONG TEAMS OF UNMANNED SYSTEMS OPERATORS

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ABSTRACT

The research presented in this paper considers the impact of communication between multiple operators controlling multiple unmanned systems. First, communication between an unmanned aerial vehicle (UAV) operator and an unmanned ground vehicle (UGV) operator was coded, to account for target identification support. Second, communication was coded to account for instances of a UAV operator providing location support to a UGV operator. Regression analyses revealed that performance only improved with high amounts of one type of communication or the other. When both types of communication occurred at the same time, performance was equivalent to doing nothing at all. Implications of these effects are discussed.

1. INTRODUCTION

As research into autonomous operations of unmanned systems develops, two different relationships are beginning to emerge around the human-to-robot ratio. First, research is indicating that individual operators are ill-suited for handling multiple unmanned assets (Chadwick, 2005, 2006). Second, teams outperform individual operators when using one or more assets (Burke & Murphy, 2004, Rehfeld, Curtis, Fincannon, & Jentsch, 2005). In light of these findings, it is quickly becoming apparent that teamwork, currently the norm in unmanned aerial vehicle (UAV) operations, is likely to (a) remain a standard in future UAV operations and (b) be adopted for all other types of unmanned systems.

Research needs to investigate how operator teams should collaborate with each other when controlling multiple unmanned vehicles. Several studies have indicated that adding a second unmanned ground vehicle (UGV), theoretically allowing an operator team to increase ground area coverage, in reality, either has no effect or actually hinders overall performance (Chadwick, 2005; Rehfeld et al., 2005). The addition of a UAV, however, has been found to improve specific dimensions of performance (Chadwick, 2005, 2008).

As a result, this study focuses on coordination using multiple heterogeneous assets for reconnaissance and surveillance.

When considering team effectiveness and performance, many studies have highlighted the importance of attending to team process (Campion, Medsker, & Higgs, 1993, Campion, Papper, & Medsker, 1996, Tannenbaum, Beard, & Salas, 1992), which refers to the interaction between teammates while collaborating on tasks. Emerging research with unmanned systems has indicated that communication is associated with situation awareness (Burke & Murphy, 2004), and can interact with individual differences to influence workload (Fincannon, Evans, Jentsch, & Keebler, 2008b). Given this, the current paper intends to explore the importance of team process by focusing on its application in the operation of multiple heterogeneous unmanned systems.

1.1 Position Localization with Multiple Systems

While the use of multiple UGVs has not been found to improve team performance, the addition of an unmanned aerial vehicle (UAV) to a UGV has been found to improve an operator's performance with respect to localizing targets in remote environments (Chadwick, 2005, 2008). Although multiple explanations have been offered for this effect, one possible explanation is that the UAV perspective provides more global "Location Support" that aids UGV operators with better understanding positions in the environment.

In the context of team effectiveness while using multiple robotic assets, it is important to consider how the UAV perspective influences the dynamic between UAV and UGV operators. If the UGV perspective is ill-equipped to provide information regarding location, it is likely to expect that UAV operators are uniquely equipped to provide "Location Support" to UGV operators. While the addition of UAV perspective has been considered in the context of individual operators, this has not been considered in the context of teams. Given this, one goal of the current study is to examine the influence of UAV "Location Support" as a team process behavior. Specifically, we hypothesized that "Location

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Support” from a UAV operator would improve the UGV operator’s ability to complete tasks and thus improve the team’s performance.

1.2 Target Identification with Multiple Systems

A second potential explanation for the positive impact of adding a UAV relates to the way the availability of the UAV can overcome inherent UGV operational limitations. For example, a UGV may encounter ground obstacles that can prevent its operator from seeing certain objectives. In these cases, availability of the aerial perspective from a UAV could overcome the UGV’s lack of a clear view. Conversely stated, a UAV might encounter visual obstructions, like tree cover or an overpass that can prevent its operator from being able to observe various objectives. A UAV/UGV operator team, therefore, may be able to assist one another in identifying targets that would otherwise not be observable by one vehicle or asset alone. We termed this “Objective Support” and hypothesized that it would improve team performance.

1.3 Purpose & Hypotheses

For the purposes of this study, we were concerned with the effects of the aforementioned processes on team performance. Specifically, we investigated the relative contributions that (a) Location Support and (b) Objective Support had on team performance in a combined UAV/UGV reconnaissance task.

Team research dictates that team processes not only have a direct influence on performance, but they can also have interactive effects on performance (Tannenbaum et al., 1992). As a result, this study also examines the significance of interactive effects of Location Support and Objective Support

2. METHOD

2.1 Participants

122 students from the University of Central Florida formed 61 two-person teams. One team member was assigned to operate a UGV, and the other a UAV. Team members were located in different places, and collaborated remotely to perform reconnaissance missions in a scaled, Military Operations in Urban Terrain (MOUT) environment (Ososky, Evans, Keebler, & Jentsch, 2007).

2.2 Apparatus

2.2.1 MOUT Facility

The MOUT facility (Figure 1) is a 1:35 scale replica of Al-Najef Iraq. Consisting of a 25ft x 18ft area, this simulation allows us to represent approximately four scaled city blocks. Unlike computer simulations, our environment is reactive. When participants drive the vehicles into objects, the objects actually move. We believe this adds fidelity and realism to the simulation, above what could be done in a computer simulation.



Figure 1. Scaled Military Operations in Urban Terrain (MOUT) environment.

2.2.2 UGV & UAV

As discussed by Ososky et al. (2007), the UGV and UAV both consist of re-engineered Remote Control (RC) vehicles that are coupled with micro-control boards, in order to allow for remote control of the vehicles via computer. The UGV is equipped with two miniature wireless video cameras. These cameras are placed in two locations on the vehicle: one as a stationary front view, and the other as a moveable (approximately 160 degrees) Reconnaissance, Surveillance, and Target Acquisition (RSTA) camera. The UAV consists of a vehicle that drives on a track hanging approximately ten feet above the facility, simulating a distance of approximately 350 feet in the air. The simulated UAV is equipped with one camera that points straight down from the vehicles position. Throughout the experiment, the vehicles could be controlled in one of two modes: Full Automation or Tele-Operation.

2.2.2.1 Full Automation

To reliably simulate robotic automation, trained confederates were located in the robotic operations room. Often referred to as a “smoke and mirrors” setup, this single blind design allowed us to fully script the behaviors of the robotic entities.

Confederates were able to see routes drawn on a map of our MOUT facility by the participants, and they then could drive the vehicles to the end of each segment (waypoints). When confederates reached the end of a waypoint, they stopped the vehicles and waited for further commands from the participants. From the participant's point of view, it seemed that they were "programming" the robots, step by step, to move along a route that they had designed before the mission started.

2.2.2.2 Tele-Operation

In tele-operation mode, we allowed the participants to take control of the RC vehicles, via their computer workstations. In case of hazardous use of the vehicles, confederates would over-ride this function. Participants were urged to only use this mode when they need to move the vehicle around a hard to see target, or go back to a previous target. If during this operation the participants move off track from the drawn path, placing the vehicle back into Full Automation will take them to their last waypoint.

2.2.3 C4I UAV Operation Room

The C4I room (Figure 2) is an office-like environment where all UAV operation takes place. Consisting of a computer station and multiple monitors, the UAV operator, depending on condition, can see views from both their own vehicle and from the UGV's front view camera and RSTA camera. An experimenter is present at all times to administer paperwork, save mission data, and answer questions about how to operate the system.



Figure 2. Display setup from the C4I room

2.2.4 Forward Observer Virtual Foxhole

The Forward Observer (FO) Virtual Foxhole is a laboratory room converted into a simulated, desert embedded bunker (Figure 3). Using projectors, the

back wall of the room displays a DVTE (Deployable Virtual Training Environment) of mountainous desert scenery, to add realism and immersion to the bunker. The participant is seated in a sandbag enclosure, complete with a camouflage netting canopy, and battlefield accoutrements including M-16 rifles, canteens, gas cans and other military paraphernalia. An experimenter is present at all times, seated outside the foxhole in the front of the room.



Figure 3. Virtual foxhole environment

2.3 Procedure

2.3.1 Training & Practice

Participants began the experiment by filling out informed consents and biographical data forms. After they finished this initial paperwork, they were then brought into the C4I room for training, regardless of the vehicle they were using. Participants were trained through a PowerPoint presentation that displayed how to operate their given vehicle, how to find and identify targets, and how to communicate to their team mate. Once they had finished the training presentation, they were free to ask questions to the experimenter. They were then given 10 minutes to study a booklet containing the possible targets they may encounter in the missions.

Following this, participants operated the vehicles through three practice missions. Each successive mission added another level of difficulty, above that of the previous missions (i.e. increase the number of objectives, increase need for coordination due to targets being placed in more difficult locations). From start to finish, participants had approximately 1.5 hours of training and practice before reaching the final mission that was used in this analysis.

2.3.2 Performance Task

The last mission was set up in a way that both vehicles needed one another in order to find all targets. For example, the UAV would be given a map with a target that was under a bridge. They would need to communicate to the UGV in order to get a view from the ground, due to the obstruction from an aerial view. Participants were given 20 minutes to

reach the entire set of objectives and identify as many targets as they could.

2.4 Measures & Analysis

Three measures were used in this analysis. In order to assess performance, a percentage (0% to 100%) score was created for each objective. This score was then combined across all six objectives to create a total percentage score (0% to 600%) that was used in this analysis.

Three raters read transcripts from team interaction during the final mission, which was used to look for specific team process behaviors. One of these measures assessed target identification support. As mentioned above, the final mission consisted of objectives that could only be reached by a UAV or a UGV. This measure was a count of the number of objectives where a team said that they would send the correct vehicle to the correct location to successfully complete the mission (Range of 0-6). Analyses indicated that this was a reliable assessment ($ICC=.80$; $\alpha=.92$).

The second process behavior focused on location support. Specifically, raters were asked to code the number of instances where a UAV operator explicitly told a UGV operator where the UGV was located in the remote environment. Analyses indicated that this assessment was reliable ($ICC=.81$; $\alpha=.93$).

3. RESULTS

As illustrated by the correlation matrix in Table 1, there was a significant correlation between Objective Support and Target Identification performance ($r = .23$). A lack of significant correlations also indicated that there was neither a direct relationship between Objective Support and Location Support nor target identification performance and Location Support.

Regression analyses revealed significant effects of the team processes on the number of targets identified during the course of the mission. Specifically, a significant interaction was found between location support and objective support on performance, $F(3, 57)=3.099$, $p<.05$, $R^2=.14$. If the UAV operator only provided Location Support, target identification improved. If, instead, both teammates only provided mission Objective Support, target identification improved. When both types of support were provided during the course of a mission, however, there was no benefit, and the number of targets identified was equivalent to missions where the teammates performed neither of the support behaviors.

Table 1
Correlation Matrix (N=61)

	1	2	3
1. Objective Support [Range: 0 - 6]	1.0		
2. UAV Location Support (UAV Nav)	.12	1.0	
3. Team Target Identification Score	.23*	-.04	1.0
Mean	1.99	0.42	1.60
Standard Deviation	1.71	0.87	0.95

* $p<.05$, ** $p<.01$

Table 2
Hierarchical Regression Analysis Reporting the Standardized Coefficient (β) Predicting the Total Percentage of Targets Correctly Identified

Variable	STEP 1	STEP 2
Objective Support (ID Support)	.24 †	.37 **
UAV Location Support (UAV Loc)	-.07	.52 †
Id Support X UAV Loc		-.69 *
R^2	.06	.14 *
ΔR^2		.08 *

† $p<.10$, * $p<.05$, ** $p<.01$

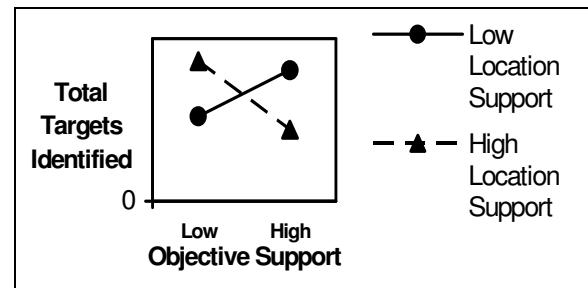


Figure 4. Illustration of the Interactive Effects of Location Support and Objective Support on the Prediction of the Percentage of Targets Identified

4. DISCUSSION

The results illustrate that one of the benefits of mixed UAV/UGV operator teams is that one asset can be used to support deficiencies associated with another asset, and vice versa. By providing improved knowledge of a vehicle's location and/or by allowing one operator to gather information on objectives that

his/her vehicle normally could not see, operator teams can work together to improve performance.

The observed interaction, however, highlighted limitations to these benefits of team support. When both types of support were given during the course of a single mission, the benefits of providing these supportive processes diminished completely. As performance was lowest for the minimal/maximal levels of communication and highest for the moderate levels of communication, the interaction here appears to resemble an “inverted U” relationship that is commonly used to describe the influence of workload on performance. For the relationship in this study, it appeared as though there were instances of too much communication, which served the purpose of overloading the team as a whole, hindering performance. Alternatively, teams might have experienced overload, which was manifest in the form of the observed communication pattern.

4.1 Implications

In the context of team performance, there are several implications of these findings. One of these could be to take a technologically centered approach to identify design principles that might aid with certain types of communication, in order to improve performance. For example, providing an aerial perspective for UGV operators working alone has been found to increase target localization performance (Chadwick, 2005, 2008). In the context of team performance, providing a UGV operator with video from an UAV has been found to reduce the amount of localization support from certain types of UAV operators (Fincannon, Evans, Jentsch, & Keebler, 2008b). Given that multiple visual perspectives appear to have this pattern of effects, it would be likely to expect visual manipulation to have the effects of improving team process and performance.

Another approach that could be developed from these findings might apply to aspects of training. For example, a training program might start by making teams aware of the pattern of effects, and could possibly empower them by teaching strategies to provide both types of communication effectively. Specific strategies could involve: learning how to communicate effectively, understanding when is (or is not) appropriate to provide support, how to recognize when a teammate is overloaded, and knowing how much information to provide at one time. To date, there is little research exploring the benefits of training programs on team performance with unmanned systems, and future research should explore this option in more depth.

CONCLUSIONS

This study identifies how operators that control different types of vehicles can support each other during a reconnaissance task. In light of the interaction highlighting the limitations of this support, future research should focus on finding methods of providing both types of support to teammates without the detrimental effects observed here. Potential solutions could be of a technical nature (e.g., improved situation displays) or could be procedural (e.g., by providing optimized procedures for the timing and amount of support that is given by one team member to another). Finally, team members may benefit from team coordination training, which would allow them to recognize and better judge when, and what type of support, is most helpful to other unmanned vehicle operators.

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