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Investigating Supervisory-level Activity Awareness Displays for Command and Control Operations

ABSTRACT

This paper describes a preliminary study that investigates new information visualization and data fusion concepts to help provide situation and activity awareness to mission commanders overseeing teams of unmanned vehicle operations engaged in intelligence, surveillance, and reconnaissance (ISR) missions. These display concepts are based on the design concept of *activity awareness* – a design approach focused on improving planning and coordination in teamwork through intelligent sharing of group activity information. In order to begin evaluating how well these display concepts facilitate supervisory-level decision making, we conducted an exploratory laboratory user experiment. In the study, participants assumed the role of a mission commander overseeing a team of three unmanned aerial vehicle (UAV) operators (played by members of the experiment team) who are each controlling three (simulated) UAVs. This paper presents results from this experiment and subsequent design revisions that were made in response to these study findings.

INTRODUCTION

Large-screen displays are becoming an integral part of command and control team environments. For instance, the battle management centers for future naval ships will include several wall-mounted large-screen displays for providing mission and ship related information. It is generally agreed that such large displays, often called situation displays, should provide information which enables the operations team to maintain awareness of the overall battlefield situation, otherwise known as the 'big picture.' However, few guidelines currently exist to help system designers determine precisely what information sources should be shown on these large displays, or what interface techniques should be used to provide this information. In addition, it is not well understood how different command and control personnel use these large displays during various mission operations. Anecdotal evidence suggests that these displays are most often used by commanding officers to gather mission status information.

Building on this anecdotal evidence, the goal of this research is to explore the potential use of large-screen displays to support team supervision in time-critical command and control operations. In particular, this project is focused on supporting commanders who oversee missions involving teams of operators interacting with highly autonomous unmanned aerial vehicles (UAVs) during time-sensitive intelligence, reconnaissance, and surveillance (ISR) activities, as might be performed by future littoral combat ship (LCS) or broad area maritime surveillance (BAMS) operations teams.

A cognitive task analysis (CTA) performed on a representative team ISR mission involving surveillance and target identification highlighted the need for the team supervisor to stay apprised of the current and expected status of team members' task activities and their progress towards meeting mission goals. To investigate appropriate interface design methods of providing this information to supervisors during command and control missions, we developed a set of interactive, large-screen mission displays, comprising a *map display* and a *mission status display*, which we presented at HSIS 2007 (Scott, Wan et al. 2007). These displays incorporate a number of interface design concepts based on the emerging design concept of *activity awareness*, a design approach in the collaborative technologies research field aimed at improved decision making, communication, and coordination in teamwork through intelligent sharing of group activity information (Carroll, Neale et al. 2003; Muller, Geyer et al. 2004; Millen, Muller et al. 2005; Carroll, Rosson et al. 2006).

In order to understand how well these display concepts facilitate supervisory-level decision making, we conducted a small laboratory user experiment. In the study, participants assumed the role of a mission commander overseeing a team of three UAV operators (played by members of the experiment team) who are each controlling three (simulated) UAVs.

To set the stage for this study, we first describe the ISR team task and the proposed mission displays, outlining the activity-awareness concepts included in these displays. Next, we describe the study method, and present the results. Finally, we discuss subsequent design revisions that were made in response to these study findings.

REPRESENTIVE TEAM ISR TASK

In order to better understand how to develop display technologies that assist ISR operations teams, a representative ISR team task scenario was developed. The task scenario involves a team of operators working together to secure a large geographic area, the team's area of interest (AOI), to ensure the safe passage of an important political convoy that will be traveling through the area in the near future. During the task, the team will be required to surveil the area for potential threats. Once hostile targets have been identified, the team must coordinate with an external strike team to engage these hostile contacts before they are within weapons range of the convoy. The team will be required to monitor incoming intelligence reports in order to extract information relating to their AOI and potentially communicate with other teams as necessary to clarify intelligence reports.

In order to secure the AOI, the team will be required to utilize a number of UAVs. Various team members will be required to monitor the progress of these UAVs as they provide surveillance of the large AOI and to reroute the UAVs from their original surveillance course, as necessary to secure the area. The team may also be required to coordinate with other teams to utilize assets outside of their immediate control to help secure the AOI.

The UAV operations team consists of three UAV operators, each responsible for controlling multiple UAVs, and one mission commander overseeing the team's mission progress. The UAV operators are responsible for supervising the progress of several UAVs surveilling the AOI, confirming potential targets identified by the UAVs' onboard automatic target recognition (ATR) systems, and coordinating with a strike team to destroy confirmed targets. This task scenario assumes advanced onboard ATR capability, as well as the use of a distributed ISR Cell that would liaise with this UAV team for any necessary detailed image analysis.

The mission commander is responsible for ensuring the safety of the convoy and for managing the workload of the UAV operators on his or her team throughout the mission.

To achieve these mission objectives, the mission commander can make several types of strategic decisions, which include requesting the convoy hold its current position if its intended path is not deemed safe for passage, requesting supplementary surveillance data from a nearby joint surveillance and target attack radar system (JSTARS), and re-tasking of one of the team's UAV assets to a different sub-AOI (requiring the handoff of the UAV asset between operators).

While there are many collaborative components to this task scenario, this phase of the project is focused on the decision-making and performance of the mission commander (i.e. the team supervisor) managing the overall tasking of the UAV operations team.

DISPLAY DESIGNS

The results of the CTA conducted on the mission commander's role in the ISR team task highlighted the importance of the mission commander staying apprised of the current and expected status of team members' task activities and their real-time progress towards meeting the mission goals. To address these issues, design concepts for providing *activity awareness* – a design approach focused on improving planning and coordination in teamwork through intelligent sharing of group activity information (Carroll, Neale et al. 2003; Carroll, Rosson et al. 2006) – were incorporated in the design of the large-screen displays.

These concepts, along with information requirements generated by the CTA, informed the design of two interactive large-screen, displays:

- a **Map Display** that visualizes positional information of relevant contacts and assets in a geographical context, as well as activity information on these contacts and assets, and
- a **Mission Status Display** that visualizes mission status information, including UAV surveillance activity progress, communication

links to external resources, and scheduled strikes on known targets.

Map Display

The main purpose of the Map Display, shown in Figure 1, is to provide an updated view of the main mission assets (e.g., convoy, UAVs, targets) in the context of the UAV team's area of interest, satisfying the geospatial information requirements generated by the CTA. The symbology used on this display is primarily based on standard military display symbology from MIL-STD-2525B (DOD, 1999), modified to satisfy the information requirements generated by the CTA for our futuristic task environment. System users, military or otherwise, will receive training to familiarize themselves with this symbology as part of any future system testing.

In particular, the map symbology is designed to dynamically change through the mission to enhance the mission commander's awareness of possible threats and operator performance issues. For example, areas of the map which have not yet been surveilled are indicated by a semi-transparent black overlay. When a UAV surveils an area, its overlay is cleared. Thus, the current surveillance progress across the UAV team is indicated by the relative amount of clear and black areas in each operator's AOI. Ideally, these areas would fade back to black as time passes and the surveillance data ages (Bisantz, Pfautz et al. 2006).

When an operator is in the process of confirming a possible target detected by a UAV's onboard ATR system, this operator and UAV-related activity is conveyed by a change in UAV symbology color, from its nominal blue color to a "target confirmation activity" orange color. Additionally, an orange target symbol is displayed on the map in the location of the detected target. This orange coloring indicates that both the UAV operator is tied up with an analysis activity and the UAV is currently unavailable for further surveillance activity until the target is confirmed. Thus, neither team "members" are available for other tasking during this period. When the operator finishes the target confirmation activity, the UAV returns to its nominal blue color and the target is displayed as red, indicating a known threat.

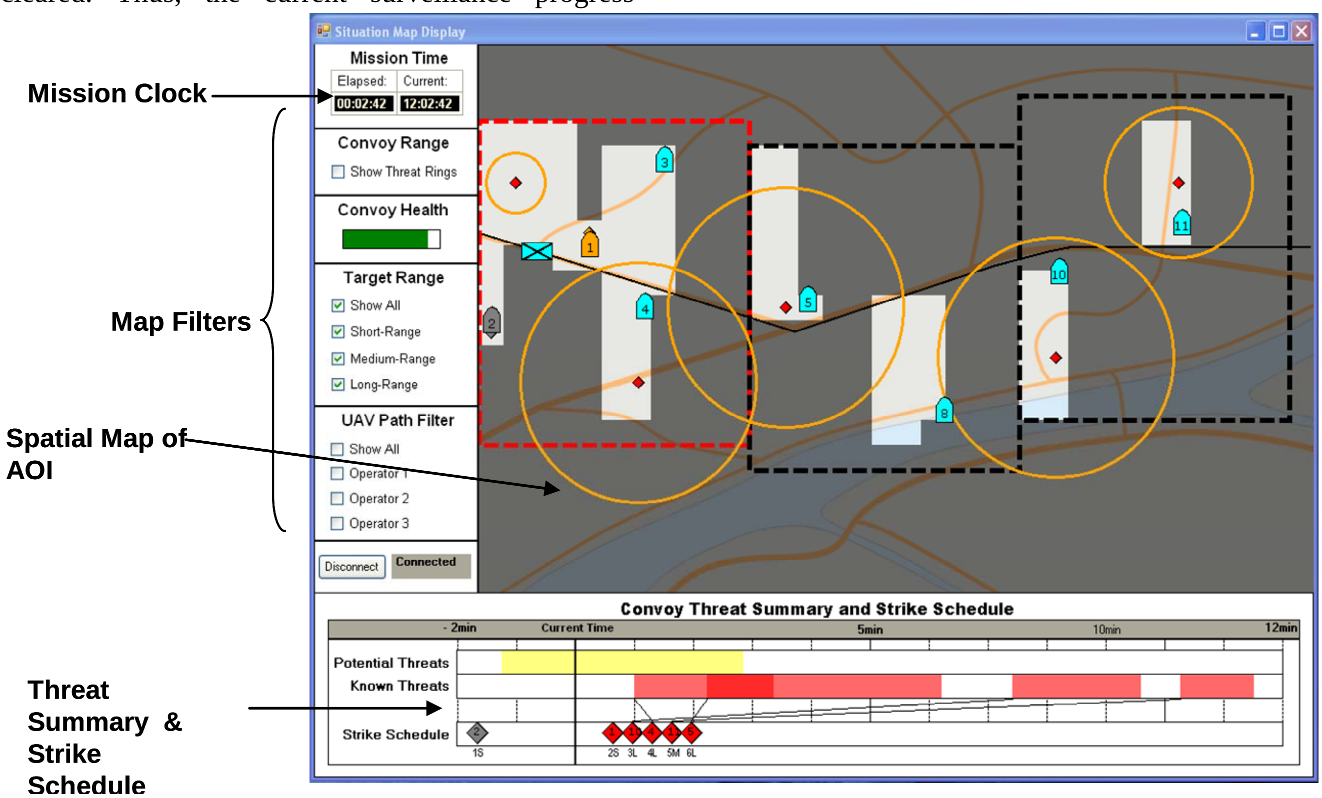

Figure 1. Map Display.

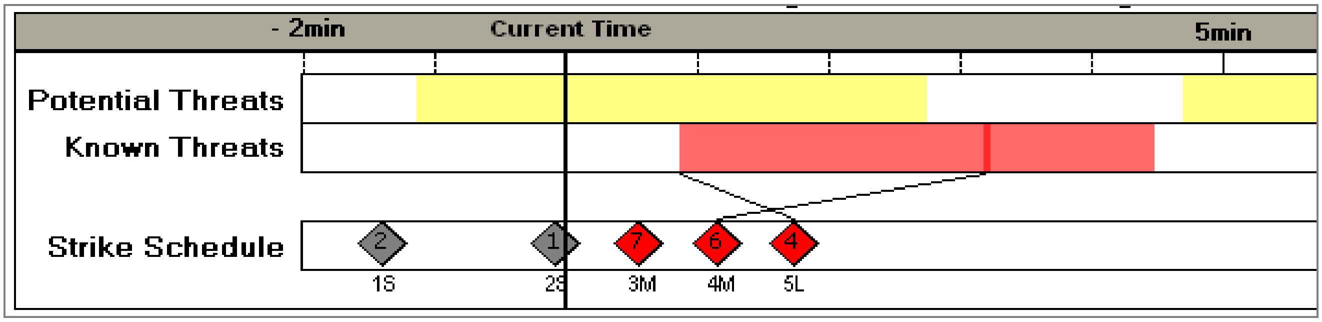

Figure 2. Strike schedule example: Threat 4M is scheduled to be destroyed 2 minutes *before* the convoy will be within its weapons range. Threat 5L is scheduled to be destroyed 1 minute *after* the convoy will be within its weapons range. Threat 3M is far enough away from the convoy's route that the convoy is not expected to pass within its weapons range, thus no corresponding 'threat window' is shown.

Some changes to the map symbology are designed to correspond to critical information also displayed on the second display, the Mission Status Display, in order to inform the mission commander of a critical status change and to direct attention to the Mission Status Display for further information on the situation.

For example, the color of the AOI boundaries changes depending on operator performance, which is tracked and displayed in more detail on the Mission Status Display. A black boundary indicates the corresponding operator is expected to meet their ISR responsibilities. In particular, the operators are predicted to surveil areas in their AOI that are within weapons range of the convoy in the near future. When an operator begins to fall behind on surveillance and is not expected to surveil all areas within weapons range of the convoy, the boundary for that operator's AOI changes to yellow. If an operator's performance is expected to reach a critically low point, their AOI boundary will change to red. In this task, critically low performance indicates that an operator has significantly fallen behind schedule in checking areas directly along the route of the convoy, perhaps due to UAV losses.

In order to help the mission commander cognitively integrate, and make appropriate decisions based on, disparate task activities occurring within the UAV team and outside the UAV team by other relevant personnel, a Convoy Threat Summary and Strike Schedule timeline is provided at the bottom of the Map Display (see Figure 2). This timeline provides a quick visual summary of whether the convoy is expected to be under known or potential threats based on the current location of the convoy, and the surveillance and strike activities of the UAV operators and the strike team. More specifically, this timeline indicates when the convoy is expected to be in range of any unsurveilled areas (i.e., a potential threat, shown as a yellow time window) or in range of a known threat (shown as a red time window).

The timeline also shows the updated target strike schedule in the context of the current and expected convoy threats. Known threats are shown as red diamonds in the last row of the timeline. The position of a known threat on the timeline indicates the scheduled time when it will be destroyed by the external strike team. If the convoy is or is expected to be within weapons range of a known threat, a black line is displayed between the target's symbol in the strike schedule and the beginning of its corresponding time window in the row above.

Since humans are adept at perceiving differences in line angles (Ware 2000), this connector line creates an emergent feature to help the mission commander identify off-nominal situations when a threat strike will not happen before the convoy will be within its weapons range. For example, when the mission commander sees a threat connector line at a vertical angle or sloping downwards to the right (e.g., the strike will be later than the convoy's arrival within the threat's weapons range), they should take action to delay the convoy and let the strike team destroy the threat before the convoy is allowed to continue.

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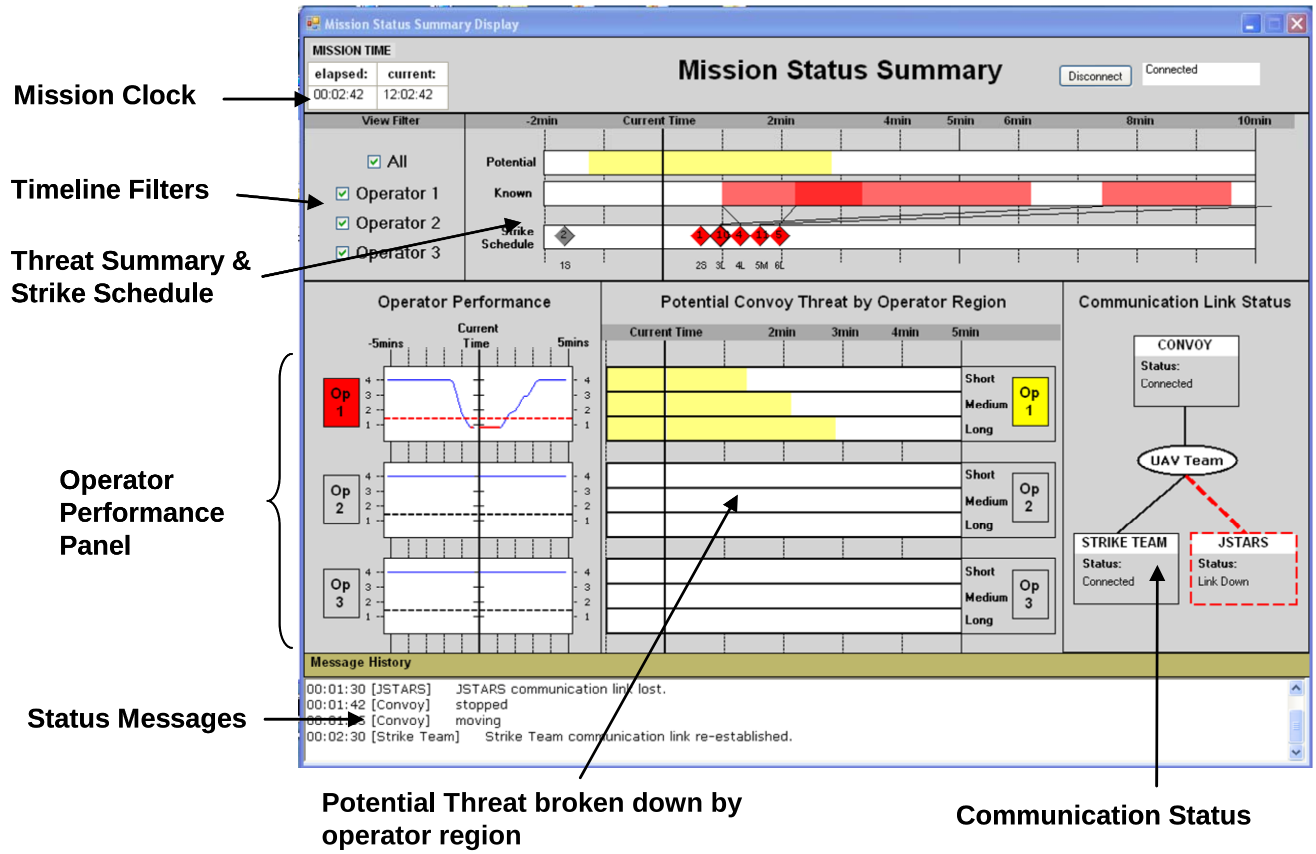

Figure 3. Mission Status Display.

Mission Status Display

The Mission Status Display shows various types of information designed to provide the mission commander current and expected status of the UAV operators' task performance, the convoy's safety level, and the UAV team's communication connections to remote contacts (see Figure 3).

The Mission Status Display contains a Convoy Threat Summary timeline (mirrored on the Map Display as described above), Operator Performance time graphs, and Potential Convoy Threat Summary timelines. The Potential Convoy Threat Summary timelines provide a timeline for each operator region (AOI) that shows expected threat level to the convoy based on planned UAV surveillance activities. Whenever the convoy is expected to be close enough to any unsurveilled areas that are within medium or short range weapons, a yellow alert is triggered to the right of the corresponding AOI timeline. Also, the corresponding operator AOI boundary will turn yellow in the Map Display.

The Operator Performance time graphs show the current and expected Operator Performance, based on each operator's ISR performance and its impact on convoy safety. If an operator's ISR performance begins to degrade, putting the convoy's safety in jeopardy, the operator's performance score decreases. When an operator's performance becomes critically low (i.e., their surveillance performance is putting the convoy in critical risk of being attacked), a red alert is triggered to the left of the corresponding time graph. The corresponding operator AOI boundary will also turn red in the Map Display.

The Mission Status Display also provides an updated view of the UAV team's current connection status to the external contacts in the Communication Link Status panel.

Finally, the Mission Status Display contains a message history box, which displays communication messages sent to the mission commander from team members and external contacts, as well as critical status messages from the system.

EXPLORATORY STUDY

To assess the usability and effectiveness of the proposed activity awareness display concepts for facilitating supervisory-level decision making, we conducted an exploratory laboratory user experiment. The primary purpose of this study was to understand the strengths and weaknesses of the proposed display concepts to understand the potential benefits of the activity-centric design approach for supporting supervisory-level decision making.

A secondary goal was to understand the strengths and weaknesses of the experimental platform in which the study was conducted. Evaluation of collaborative technologies, especially for complex task domains, is an ongoing challenge for researchers (Inkpen, Mandryk et al. 2004). A long-term goal of this research program is to contribute improved study methodologies that provide greater insight into a technology's impact on teamwork.

Since the task scenario in this project involves a futuristic UAV team mission, a software simulation environment was developed to emulate the activities of the UAVs (e.g. automatic route following and onboard automatic target recognition) and any complex operator-UAV interaction (e.g., UAV handoff between two operators, UAV re-routing, and sensor manipulations for target detection). In the study, participants assumed the role of the mission commander overseeing a team of three UAV operators (played by members of the experiment team) engaged in the ISR task described above.

Participants

Eight undergraduate students from Boston-area universities completed the study, six of whom were members of the US Naval Reserve Officers' Training Corps (NROTC) program. Participants were paid $30 for their participation (NROTC participants donated this compensation to their unit).

Experimental Design

As this was a preliminary experiment primarily focused on assessing the usability and subjective assessment of the display concepts and experimental platform, a straightforward design was used in which all participants experienced the same experimental procedure under the same conditions, explained in more detail below. Participants completed the experimental task under two levels of mission tempo, one that required a moderate level of replanning, and a second that required a high level of replanning.

Use of Deception and Experiment Confederates. In order to reduce the variation in possible UAV operator behavior under the command of different participant mission commanders, and to enable the introduction of certain, pre-planned "incidents" during experimental trials, members of the experiment team assumed the role of the UAV operators. This study method is referred to as using experiment "confederates" (Duncan Jr. and Fiske 1977). The confederates were scripted to perform certain operator behaviors at pre-defined points in the experimental trials to introduce situations to which the "real" participants must respond. Such use of confederates, along with pre-defined event generation in the simulation environment, ensures that specific, mission conditions arise in the dynamic task environment in order to assess the activity awareness display concepts during these mission states.

A challenge of using experiment confederates is to ensure the real participants believe the confederates are also study participants in order to invoke realistic team interaction. To address this issue, our confederates acted as they did not know each other or the experimenter. Also, participants were told a deceptive story that the "UAV operator" participants had been trained on their experimental task in a previous session. Post-experiment interviews confirmed that participants believed this story. Finally, the fact that the confederates were foreign graduate students and interns added to the plausibility of their pre-planned poor performance on a US-based map navigation task.

Experimental Setting

The study took place in an experimental laboratory designed to emulate a small command center, located in the MIT Humans and Automation Laboratory. In this simulated command center, the UAV team mission commander (participants) had access to the two 42-inch (1024x768 pixels), wall-mounted interactive plasma screens that displayed the supervisory-level interfaces described above: the Map and Mission Status Displays. In order to implement command decisions in the simulated task environment, the mission commander used a networked, 14.1-inch, Fujitsu tabletPC. This device was located on a wooden podium positioned near the large displays to reduce arm fatigue of holding the display throughout the experimental sessions.

The UAV operators (confederates) sat at separate, networked, personal computers containing three 17-inch LCD displays. One LCD was dedicated to showing the UAV operator display, a scaled down version of the Map Display described above. This interface was tailored to show a zoomed in view of the operator's assigned AOI in the map, and the corresponding convoy threat summary information on a timeline below the map. Whenever the UAV operator was required to perform the Target Search task, described below, it would display on a second LCD. These operator workstations were located near the wall displays to allow the mission commander to easily assist the operators when necessary.

The simulated task environment ran from a computer server located just outside the experimental laboratory, next to a viewing glass that enabled the experimenter to monitor participants' performance. The experimental interfaces were developed in the Microsoft C# .NET programming language. Networking and data sharing across experimental computers was implemented using the Grouplab.Networking collaboration software toolkit (Boyle and Greenberg 2006).

Experimental Tasks

Mission Commander ("Real" Participants)

Each participant was asked to assume the role of the UAV operations mission commander of the ISR task described above. Participants were given the mission goals of keeping convoy safe, surveilling all roads in the team's AOI for the safety of future convoys, and of managing the UAV operators' workload. The mission commander used the simulated information displayed on the Map and Mission Status Displays to maintain awareness of the mission status. If team's mission performance degraded and a strategic decision was required, the mission commander could use the tabletPC interface to implement a number of strategic decisions, including holding the convoy in its current position, requesting supplementary surveillance data from a nearby JSTARS, and re-tasking an underutilized UAV to take over the surveillance route of a second UAV which has been destroyed by an enemy threat.

If the UAV operators, and their corresponding UAVs, fell behind on their surveillance performance, putting the convoy's safety at risk, the mission commander could intervene and assist the operator with their target search task (described below).

As a secondary, awareness task, the mission commander was required to report any occurrence of a "late strike" during the mission. That is, occurrences of an identified threat being scheduled for destruction by the strike team after, or within 30 seconds of, the convoy's plan to arrive within weapon's range of that threat.

UAV Operators (Confederates)

The experiment confederates assumed the role of the UAV operators on the UAV team. Each operator was responsible for monitoring the surveillance and health status (whether the UAV was active or not), of their assigned UAVs. When one of their UAVs' onboard ATR system detected a possible threat, their operator station would launch a map-based, "target search" window (the "City Search program", described in (Crandall and Cummings 2007)). This target search task involved finding a target city within a map of the USA. The task would begin each time with the full, zoomed-out view of the USA displayed and the name of the target city shown in text above the map. Operators had to zoom into the respective area of the map to reveal more detailed information, including city names. Once found, the city name had to be selected before the window would close and they could release the associated UAV from its hovering location above the detected threat.

This target search task was designed to emulate the type of geospatial manipulation and visual analysis task operators might be required in actual UAV operations. The corresponding UAV remains in a hover state above the potential target location until the operator completes this target search task.

The confederate operators' deceptive behavior was triggered by a cryptic message displayed on specific search task instances. In these instances, the confederate operator had to pretend to have difficulties completing the task, for instance, by zooming into the wrong geographic region, or not noticing the target city. In short, by performing behavior that would appear to the study participants to be due to the target city being located in a crowded state or to operator being unfamiliar with American geography.

A duty of the mission commander participants was to help the operators with this target search task when the operators were having particular difficulties and their surveillance performance was degrading.

Procedure

Each participant began by completing an informed consent form and a background questionnaire that gathered demographic information. Next, they completed a computer-based PowerPoint tutorial that outlined the experimental tasks and explained the software interfaces (30-45mins, depending on how familiar participants were with the military domain).

The participant was then introduced to the UAV operators (confederates), and the UAV operators were introduced to each other (who of course actually knew each other, but this process was used to enforce the deception of the UAV operators being actual study participants). The UAV operator task was then briefly explained to the participant, and also to provide a "refresher" to the UAV operators, who supposedly had received previous training on this task.

The team then completed two 10-minute practice trials in the experimental task environment. In the first practice trial, the experimenter provided comments, explained subtle functionalities of the interfaces, and answered any questions the participant had. The participant completed the second trial without help from the experimenter, but could ask questions once they had completed the trial.

Finally, the team completed two 15-minute experimental trials. The first trial was a moderate-tempo mission scenario and the second trial was a high-tempo mission scenario. Following the final task scenario, the deception aspect of the study was revealed to the participant, and they were asked if they would be willing to continue participating in the wrap-up activities. (All participants chose to continue.) Next, they partook in a semi-structured, retrospective interview with the experimenter, which inquired about their decision making strategies while reviewing a screen replay of the large-screen interfaces captured during their final experimental trial. Finally, participants completed the Cummings-Myers Display Quality Rating Scale (Cummings, Myers et al. 2006), were paid, and thanked for their participation.

Data Collection

Participants' interactions with the experimental software and their command decisions were logged to a data file and recorded using the TechSmith Camtasia (http://www.techsmith.com) screen-capture software. Observer field notes were recorded during the experimental trials to note interesting decision-making and interaction behaviors. Notes were also recorded during the semi-structured interviews. Participant interactions in the physical team testing environment and with other team members were captured on audio and videotape. Demographic and experience data were also collected on the background questionnaire.

STUDY RESULTS

As a preliminary study to begin understanding the effectiveness of activity awareness displays for command and control operations, and to understand where design improvements are needed, the study analysis focused on identifying which display components participants relied on during the mission scenarios and the effectiveness of the current design of these components. The retrospective interview data were particularly illuminating for this purpose, along with comments participants provided with their Cummings-Myers Display Quality Ratings. Before discussing these results, we first establish that the study design and experimental setting was effective for engaging participants in a team context and in a leadership role during the UAV mission operations.

Team Engagement

The video data established the credibility of a team environment. These data provided substantial evidence of the participant interacting with the study confederates, both during the trials and in the down time between trials. The videos also show many occurrences of the mission commander participants assisting the UAV operators with the target search task (4-12 instances of assistance across participants in their final trial). Such interactions demonstrate that participants were engaged in the overall team activity and were not just interacting alone with the system via their mission commander displays. Analysis of the video data in conjunction with the logfile data also revealed that participants who were more engaged with the UAV operators, and more proactive in offering help, generally performed better in the overall mission task. In particular, teams in which the mission commanders offered no assistance or delayed assistance to the UAV operator responsible for AOI 3 (i.e., Operator 3), performed worse than participants who assisted Operator 3 well before the convoy was approaching or had arrived in AOI 3.

Use of Mission Commander Displays and Activity Awareness Display Components

The retrospective interview data revealed that all participants used the Map Display as their primary task display. Only a few participants regularly scanned the Mission Status Display, while most used this display to further investigate or confirm their conclusions about incidents indicated by the Map Display. Not surprisingly, the Map Display contained most of the mission critical data, whereas the Mission Status Display was designed to provide more details on the information provided on the Map Display. One exception to this was the Communication Link Status display component located on the Mission Status Display. Participants tended to ignore this information, and, thus many were confused when a command intervention did not work due to a communication link outage.

The map and the Convoy Threat Summary, both located on the Map Display, were consistently reported to be the most useful and compelling display components for performing the mission.

Map. Aside from standard symbology, the activity-centric aspects of the map that participants found most useful included the surveillance overlay and the UAV status changes. The shading to indicate which areas of the team's AOI had been surveilled was reported to be extremely valuable. The degree of shading on the map provided a quick snapshot view of the team's current surveillance progress and of the convoy's relative position to any unsurveilled areas. It also provided an ongoing animation view of team activity, a point that will be discussed further below.

Participants also found the UAV color status changes useful. Most participants reported that when a UAV symbol turned orange (indicating the UAV has detected a target), they would monitor how long the UAV remained in that state in order to determine when an operator may need assistance. Several participants reported that this display change would also trigger an analysis of the surrounding area to determine the potential impact of a threat at that location, and of the corresponding UAV getting behind on its planned surveillance route. Most participants also reported that the UAV color change to gray was useful for knowing which UAVs were no longer available.

One participant felt that the color changes were not that useful, but instead she reported that she relied on the visual cue of a UAV ceasing to move in the map (i.e. ceased animation of the darks areas of the map being revealed as the UAV passed over it) in a certain area of the map. However, lack of UAV movement in the map is, in fact, ambiguous, since it could either indicate that a UAV has detected a potential threat or that it has been destroyed or otherwise unavailable. Thus, simply relying on the UAV movement in the map would require further investigation, and thus additional communication overhead, to determine the cause of the change in UAV movement.

Many participants found only the red AOI boundary changes useful, where a yellow boundary alert indicated moderate operator surveillance issues, and a red boundary alert indicated severe surveillance delays along the convoy route. Several participants reported that they did not understand the AOI boundary change alert; however, even in some of these cases the alerts were useful in initiating a closer investigation of the mission situation, as indicated by the following comment, "[I] didn't know what the AOI border color changes meant…However, they did grab [my] attention and [then I] would investigate that AOI on the map."

Convoy Threat Summary. The integrated visual summary of the convoy's current and expected safety status relative to the team's mission performance and the strike team's activities provided by the Convoy Threat Summary was reported by all participants to be extremely valuable. They used this display component to identify problems with the team's overall mission performance, which in turn helped to determine when command interventions were required.

Design Issues

Though most of the activity-centric display concepts were found to be useful for commanding the UAV mission, as described above, the retrospective interviews helped to identify opportunities for design improvement, both to the interfaces and to the experimental platform in general.

Display Issues. Two primary display issues arose during the interviews, one related to the Potential Convoy Threat panel on the Mission Status Display and the second related to the UAV status color changes. Participants consistently felt the Potential Convoy Threat panel was confusing and generally redundant. They felt that the shading information provided directly on the map was much more useful to convey region-specific surveillance information, and that the Convoy Threat Summary was sufficient for highlighting when the team's surveillance delays would affect the convoy's progress.

Some participants reported that while the UAV status color changes were helpful for determining when to assist a UAV operator in the target search task, it was sometimes difficult to determine how long a UAV had been displayed as orange, especially if other things were happening in the mission scenario. Thus, it was often difficult to judge when operator assistance was necessary. One participant suggested that "a timer next to the orange UAVs [would be useful] to see how long someone's been doing a particular task."

Experimental Platform Issues. Most participants reported being well engaged in the mission scenarios and felt that they were sufficiently complex to offer significant command challenges, especially during the high tempo trial. However, the interviews and analysis of the logfile data revealed that increasing the realism of the entity behavior may help to elicit richer decision making strategies and to increase engagement in the mission operations.

In particular, many of the entity behavior simulated in the experimental platform produced binary results, which led to simplistic decision making. For example, a convoy passing within weapons range of a known threat for a short period of time would incur the same penalties as if it stayed within weapons ranges of a known threat for a prolonged period of time. Participants felt that improving the realism of this type of entity interaction was needed to elicit more complex, and more realistic decision making behavior and strategies.

DISPLAY REDESIGN

The participant feedback reported above was used as the basis for a redesign of the Mission Status Display in order to eliminate ineffective display components and to improve the efficacy of the activity awareness display concepts that remained. In particular, the Potential Convoy Threat panel was removed from the middle of the interface. This panel was replaced with a visual summary of the current tasking of each of the team's UAVs, organized by UAV operator (Figure 4). For example, when a UAV and its operator are engaged in target identification activities, the symbol representing that UAV will turn orange, corresponding to the UAV color change in the map. This display component also provides timing data to assist with command decision making. For example, when a UAV and its operator are engaged in target identification, the time-on-task information is given, as well as the estimated time this task should take.

CONCLUSIONS

The paper presented a preliminary study of activity-centric interface design concepts incorporated into a set of large-screen displays designed to provide a mission commander up-to-date awareness of team members' current and future activity in relation to the overall mission goals. In the reported study, participants assumed the role of a mission commander overseeing a team of three UAV operators in a simulation-based experimental testbed.

Study results indicate that participants found the activity awareness information integrated into the map display and the Convoy Threat Summary timeline visualization particularly useful for understanding the overall mission situation and prioritizing the team's current problems in the context of the overall mission priorities.

Out investigation of interface design strategies for supporting command-level decision-making complements existing efforts to develop appropriate large-screen display environments for military command and control, such as the TADMUS, Knowledge Wall, and Command 21 projects (Moore and Averett 1999; St. John, Manes et al. 1999; Oonk, Smallman et al. 2001; Oonk, Rogers et al. 2002) Those efforts focused on developing optimal physical display configurations and virtual window layouts within those configurations, as well as on developing interface design concepts to support decision making

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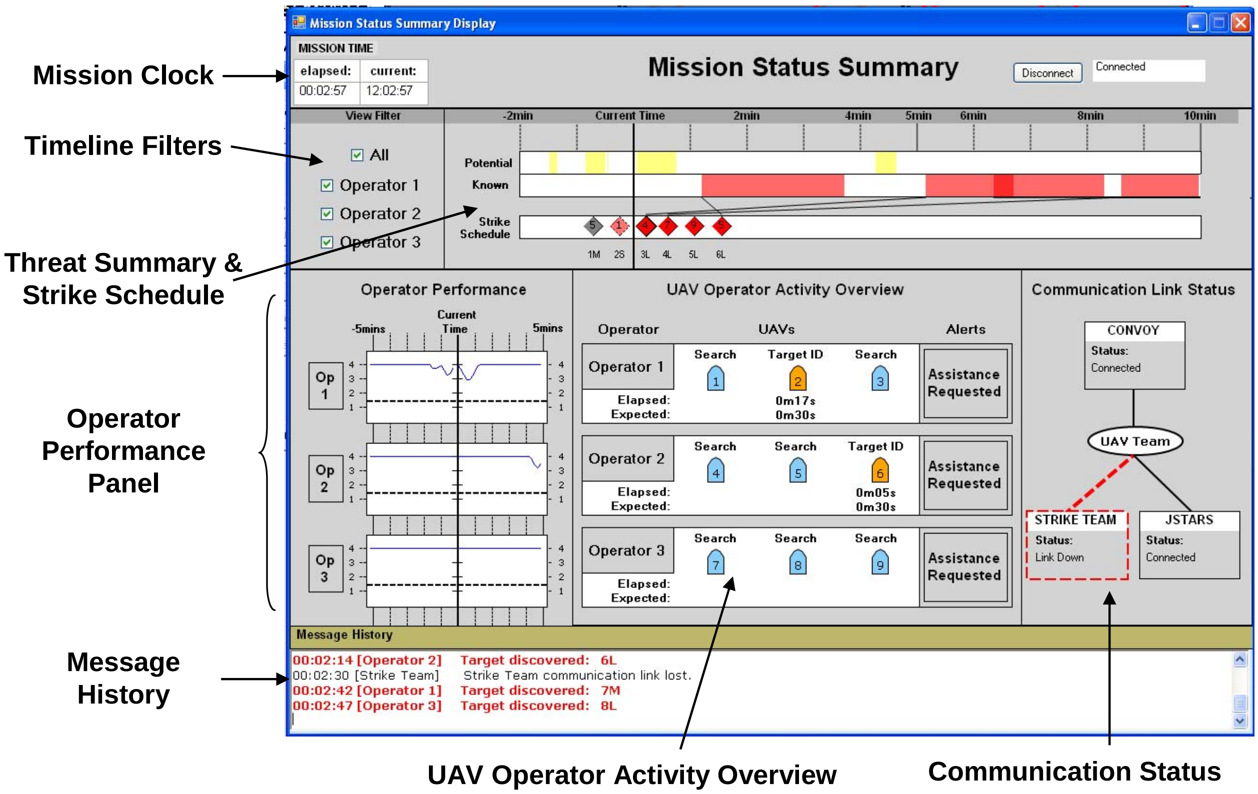

Figure 4. Redesigned Mission Status Display.

in command environments. This work augments these efforts by providing alternative display concepts that could be applied to the mission interfaces in those proposed display environments.

Although the designs proposed by this project used the concept of activity awareness to provide decision-support for the mission commander, the most effective visual representation of this information will continue to be explored as results from future studies are obtained.

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