LASSOing HRI: Analyzing Situation Awareness in Map-Centric and Video-Centric Interfaces

Jill L. Drury
The MITRE Corporation
202 Burlington Road
Bedford, MA 01730
+1-781-271-2034
jldrury@mitre.org

Brenden Keyes
University of Massachusetts Lowell
Computer Science Department
Lowell MA 01854
+1-978-934-3385
bkeyes@cs.uml.edu

Holly A. Yanco
University of Massachusetts Lowell
Computer Science Department
Lowell MA 01854
+1-978-934-3642
holly@cs.uml.edu

ABSTRACT
Good situation awareness (SA) is especially necessary when robots and their operators are not collocated, such as in urban search and rescue (USAR). This paper compares how SA is attained in two systems: one that has an emphasis on video and another that has an emphasis on a three-dimensional map. We performed a within-subjects study with eight USAR domain experts. To analyze the utterances made by the participants, we developed a SA analysis technique, called LASSO, which includes five awareness categories: location, activities, surroundings, status, and overall mission. Using our analysis technique, we show that a map-centric interface is more effective in providing good location and status awareness while a video-centric interface is more effective in providing good surroundings and activities awareness.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: Evaluation/methodology, graphical user interfaces, screen design.

General Terms
Measurement, Performance, Design, Experimentation, Human Factors.

Keywords
Situation Awareness (SA), Human-Robot Interaction (HRI), Urban Search and Rescue (USAR).

1. INTRODUCTION
Imagine robots entering a house that has been devastated by an earthquake. The house is too structurally unsound for humans to enter to search for possible survivors, so the robots must be directed from a distance. When controlling robots remotely, the operators are totally dependent upon the robots' user interfaces to glean the information necessary to understand the robots' locations, surroundings, activities, and status.

Much work has been done in the design of such interfaces for urban search and rescue robots, including at the Idaho National Laboratories [Bruemmer et al. 2005; Nielsen et al. 2004], Brigham Young University [Nielsen and Goodrich 2006; Nielsen et al. 2005], Swarthmore College [Maxwell et al. 2004], and the University of Massachusetts Lowell [Baker et al. 2004]. Despite all of this work there is still no consensus on the best way to provide awareness (usually called situation awareness, or SA) via a robot's user interface. Yet having good SA is so critical that operators will stop everything else that they are doing and spend an average of 30% of their time doing nothing but acquiring or re-acquiring SA, even when they are performing a time-sensitive search and rescue task [Yanco and Drury 2004].

Based on the importance of situation awareness, our research aims to understand which interface design approaches tend to provide better SA. In our observations of search and rescue robot systems, we have noted that many of these systems have interfaces that fall into one of two categories. This study reports on a head-to-head comparison of how well one search and rescue system from each category provides SA to first responders performing typical tasks under controlled conditions.

We term the two interface categories video-centric and map-centric. In a video-centric system, one or more video feeds form the primary means for conveying information. A video display is usually the largest visual element in a video-centric system (often taking up more than 50% of a display screen) and is the focus of attention for much of the time. In a map-centric system, one or more types of map representations are the largest and most prominent visual element. In our previous work, we have described search and rescue robot interfaces in terms that make it apparent which systems feature video versus maps most prominently [Yanco, Drury and Scholtz 2004; Yanco and Drury, to appear]. In this paper, System A was designed with a map-centric graphical user interface (GUI) while System B was designed with a video-centric GUI. The systems are described below in section 3.

Besides the insights gained from the comparison of the systems, the contributions of this paper include the first use of the LASSO SA analysis technique that we developed based on our definition of human-robot interaction (HRI) awareness [Drury et al. 2003].

Because SA is a key concept for our research, we discuss it in the next section, followed by descriptions of Systems A and B in section 3. Section 4 describes our experimental design and new LASSO analysis technique prior to discussion and results in section 5. Conclusions may be found in section 6.

2. SITUATION AWARENESS
While operators of remote robots often speak of the concept of SA, it is difficult to define this term precisely. In fact, the Royal Aeronautical Society published a summary of over twenty definitions of SA [RAS 2003]. The most widely accepted definition of SA was developed by Endsley [1988] as "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status

in the near future." Endsley's definition proved too general to be useful as an analysis tool in our studies of HRI, however. Thus, in our previous work we developed a more fine-grained definition of SA that was tailored for HRI [Drury et al. 2003]. Expressed as a five-part definition to capture the asymmetric needs of humans and robots working in teams, three of the parts of the definition are relevant in the case of one human working with one robot:

> *Human-robot:* The understanding that the human has of the location, activities, status and surroundings of the robot. Further, the understanding of the certainty with which the human knows the aforementioned information.
>
> *Robot-human:* The knowledge that the robot has of the human's commands necessary to direct its activities and any human-delineated constraints that may require a modified course of action or command noncompliance.
>
> *Human's overall mission awareness:* The human's understanding of the overall goals of the joint human-robot activities and the moment-by-moment measurement of the progress obtained against the goals.

While the robots need to be "aware" of specific types of information, we made the assumption that robots were receiving the human operator's commands and had sufficient pre-programmed constraints; thus we did not analyze robot-human awareness. Instead, we concentrated on human-robot awareness cases where the operator made statements that indicated that he or she did or did not have a good understanding of the robot's **l**ocation, **a**ctivities, **s**urroundings, **s**tatus, or **o**verall mission (LASSO) at the moment when the statement was made.

Adding to the potential confusion caused by a lack of complete consensus on what definition of SA ought to be used in any given situation is the fact that SA measurement is very much an inexact science. Whole books such as Endsley and Garland [2000] have been written to address the difficult task of measuring SA.

There are three general categories of SA measurement techniques: explicit, implicit, and subjective [Hjelmfelt and Pokrant 1998]. One way to measure SA is to interrupt someone's task to ask him or her questions about the situation; the degree to which he or she can answer the questions correctly yields an *explicit* performance measure. Such a technique can be disruptive enough to either degrade a subject's SA or, conversely, train someone to keep track of the aspects of the situation that he or she is being questioned on. Another class of SA measurement techniques, called *implicit* performance measures, does not involve interrupting the subject but also has drawbacks. Implicit measures focus on examining how well a task is performed, except that how well someone completes a task is not solely due to a person's SA. Finally, it is always possible to ask someone to rate their own level of SA, but such *subjective* measures are notoriously unreliable. Different people have different threshold levels for describing SA as "good," "fair," etc. and people who are trained to maintain SA, such as air defense system operators, may be reluctant to say that they have not maintained SA at all times.

The LASSO technique is based on analyzing what experiment participants say when they are encouraged to "think aloud" [Ericsson and Simon 1980] while they are performing their tasks. Since these utterances can reveal what participants think about their SA, LASSO could be classified as subjective. But unlike some subjective techniques that involve experiment participants waiting until the end of the trial to rate their own SA, a LASSO analysis can provide information regarding how participants' SA changes on a moment-by-moment basis.

We describe LASSO in more detail below after we present the two systems that we studied.

3. SYSTEM DESCRIPTIONS

We do not identify the two systems due to Institutional Review Board anonymity requirements. They had similar hardware (System A used an iRobot ATRV-Mini while System B had an iRobot ATRV-JR) and similar autonomy modes. The primary difference, explored in this paper, is the design of their user interfaces.

System A's interface, shown in Figure 1, combines 3D map information (denoted by blue blocks) with a red robot avatar in the map. The video window is displayed in the current pan-tilt position with respect to the robot avatar. The video window swings around and is displayed in a changing trapezoidal shape based on the pan-tilt angle being used at any given time. The robot avatar stays in the center of the screen with the 3D map prominently around it. The operator can place markers in the environment to represent objects or places of interest. Red triangles pointing towards obstacles will appear if the robot is blocked in that direction. The operator can change the view of the map, moving between a robot-centered perspective and an elevated view of the 3D map; an overhead view of the map is also provided in the lower left hand corner of the interface.

In contrast to System A, System B's interface relegates the map to an edge of the screen (System B's interface is shown in Figure 2). Additionally, the map window can be toggled to show a view of the current laser readings ("laser zoom view"), removing the map from the screen during that time. The interface has two fixed video windows. The larger displays the currently selected camera (either front- or rear-facing); the smaller shows the other video window and is mirrored to simulate a rear-view mirror in a car. Information from the sonar sensors and the laser rangefinder is displayed in the range data panel located directly under the main video panel. When nothing is near the robot, the color of the box is the same gray as the background of the interface, to indicate nothing is there. As the robot approaches an obstacle at a one foot distance, the box will turn to yellow, and then red when the robot is very close (less than half a foot). The ring is drawn in a perspective view, which makes it look like a trapezoid. This perspective view was designed to give the operator the sensation that they are sitting directly behind the robot. If the operator pans the camera left or right, this ring will rotate opposite the direction of the pan. If, for instance, the front left corner turns red, the operator can pan the camera left to see the obstacle, the ring will then rotate right, so that the red box will line up with the video showing the obstacle sensed by the range sensors. The blue triangle, in the middle of the range data panel, indicates the true front of the robot.

To summarize the fundamental differences between the two interfaces: in System A's map-centric interface, the 3D map of blue blocks is placed in the center of the screen, often occludes the video, and seems to "jump out" at operators. System B's video-centric interface was designed so that virtually everything is on or immediately around the primary video window.

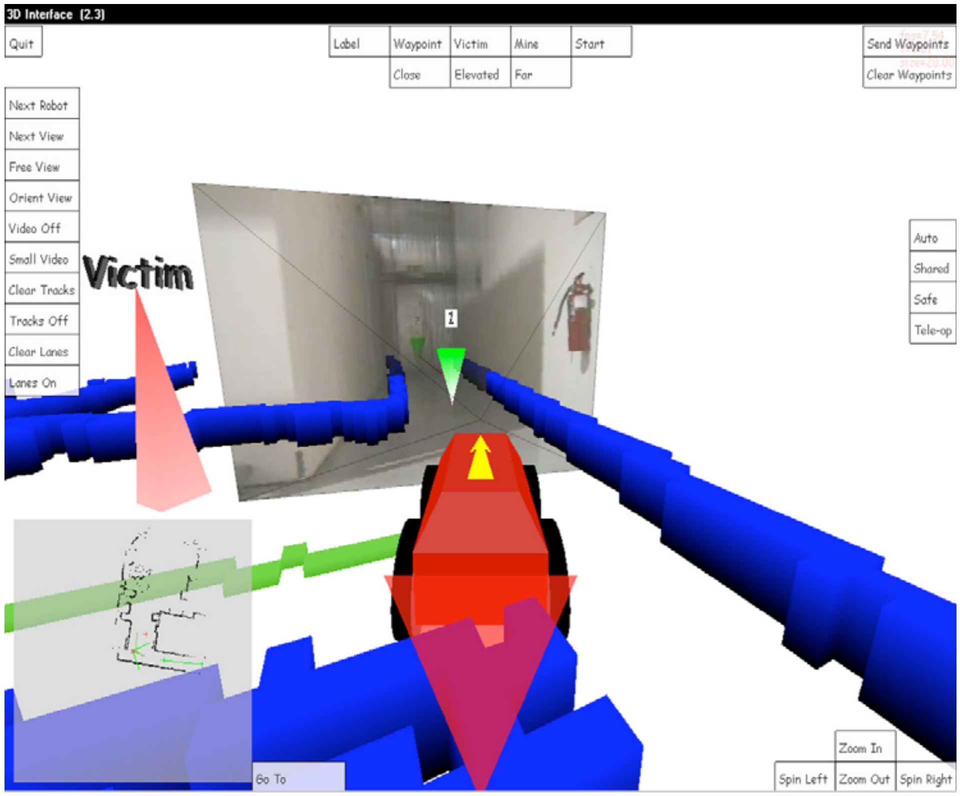

Figure 1. System A's Interface

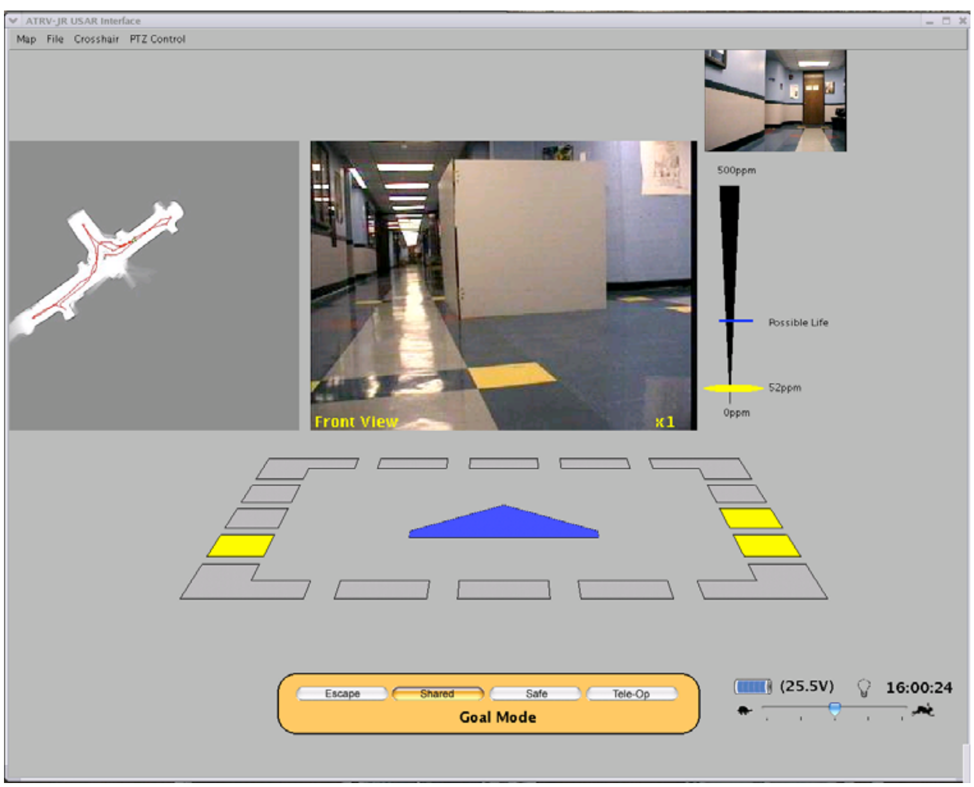

Figure 2. System B's Interface

4. METHODOLOGY

4.1 Experiment Design

Because one goal of usability testing is to determine participants' understanding of the work environment (a component of situation awareness), we designed our experiments using best practices from usability testing [e.g., Dumas and Redish 1993; Mayhew 1999; Rubin 1994]. Since we wished to see if there were differences in situation awareness engendered by the two systems, we designed a within-subjects experiment with the independent variable being interface type. Eight people (7 men, 1 woman), ranging in age from 25 to 60 with search and rescue experience, agreed to participate. The tests were conducted in the Reference Test Arenas for Autonomous Mobile Robots developed by the National Institute of Standards and Technology (NIST) [Jacoff et al. 2001; Jacoff et al. 2000].

We asked participants to fill out a pre-experiment questionnaire so we could understand their relevant experience prior to training them on how to control one of the robots. We allowed participants time to practice using the robot in a location outside the test arena and not within their line of sight so they could become comfortable with remotely moving the robot and the camera(s) as well as with the different autonomy modes. Subsequently, we moved the robot to the arena and asked them to maneuver through the area to find victims. We allowed 25 minutes to find as many victims as possible, followed by a 5-minute task that probed the operator's SA level more explicitly. After task completion, we took a short break during which an experimenter asked several Likert scale questions. Finally, we repeated these steps using a different robot, ending with a final short questionnaire and debriefing. The entire procedure took approximately 2 1/2 hours.

The specific tasking given to the participants during their 25-minute runs was to "fully explore this approximately 2000 foot space and find any victims that may be there, keeping in mind that, if this was a real USAR situation, you'd need to be able to direct people to where the victims were located." Additionally, we asked participants to think aloud during the task. After this initial run, participants were asked to maneuver the robot back to a previously seen point, or maneuver as close as they could get to it in five minutes. Participants were not informed ahead of time that they would need to remember how to get back to any particular point.

We counterbalanced the experiment in two ways to avoid confounders. Five of the eight participants started with System B and the other three participants began with System A. (Due to battery considerations, a robot that went first at the start of the day had to alternate with the other system for the remainder of that day. System B started first in testing on days one (2 participants) and three (3 participants). System A started first on day two (3 participants).) Additionally, two different starting positions were identified in the arena so that knowledge of the arena gained from using the first interface would not transfer to the use of the second interface; starting points were changed between experiment participants. The two counterbalancing techniques led to four different combinations of initial arena entrance and initial interface. While a complete discussion comparing the performances of the two systems can be found in Yanco et al. [2006], we summarize the relevant performance results below in section 5.1.

The primary sources of data for this SA analysis were the videos of the robot in the arena and of the experiment participant while operating the robot. We used the think aloud method as a window into the operator's moment-by-moment understanding of the robot's location, surroundings, status, and activities. We transcribed the operator's utterances and coded them according to the coding scheme we defined for this analysis. We also used maps of the robots' traversal through the arena made by a researcher specifically assigned to chart the robot's progress and interaction with the environment.

4.2 LASSO Technique for SA Analysis

Based upon our definition of SA for human-robot interaction, we designed the LASSO technique in which we classified operators' utterances as positive, neutral or negative in each of five awareness categories:

- **L**ocation awareness,
- **A**ctivity awareness,
- **S**urroundings awareness,
- **S**tatus awareness, and
- **O**verall mission awareness.

These five categories were derived directly from the "human-robot" and "human's overall mission awareness" portions of the HRI awareness definition described in section 2.

For purposes of this analysis, we defined an *utterance* as a block of statements on the same topic, normally pertaining to the action that an operator is taking, either in response to a specific action that the robot is taking or in response to the state of the robot.

Location awareness was defined as a map-based concept: orientation with respect to landmarks. If an operator was unsure of his or her location, this constituted negative location awareness. Positive location awareness was recorded when the operator noted correctly that he or she had seen a particular landmark before.

Activity awareness pertained to an understanding of the progress the robot was making towards completing its mission, and was especially pertinent in cases where the robot was working autonomously. The human needed to know what the robot was doing at least so that he or she understood whether the robot was doing what it needed to do to complete its part of the mission. Whenever the operator said something about the robot not moving, for example, this was interpreted as awareness of the robot's activity and thus was positive. Negative activity awareness was recorded when the operator did not understand how the robot was moving, particularly during autonomous operations.

Surroundings awareness pertained to obstacle avoidance: someone could be quite aware of where the robot was on a map but still run into obstacles. An operator was credited with having positive surroundings awareness if he or she knew that they would hit an obstacle if they continued along their current path. When operators indicated that they were unable to move for some reason but didn't indicate why, there was no way to determine whether they had adequate or inadequate understanding of their surroundings (hence we rated this "neutral"). If the operator noted that the robot was not moving (and thus had positive activity awareness) but didn't know why and something was blocking them, we coded this as negative awareness of surroundings.

Status awareness pertained to understanding the health (e.g., battery level, a camera that was knocked askew, a part that had fallen from the robot) and mode of the robot, plus what the robot was capable of doing in that mode, at any given moment. If the operator noted that the robot was not moving (positive activity awareness) and knew that there was something blocking them but didn't know why the robot wasn't moving, we coded this as negative awareness of status (in other words, the operator was unaware the robot's current mode, designed to prevent the robot to stop before bumping into obstacles, was keeping the robot from moving).

Overall mission awareness was defined as the understanding that the humans had of the progress all of the robots and other humans, as a coordinating group rather than individuals, were making towards completing the tasks involved in the mission. Since only one human and one robot performed the tasks at any given time, and since the tasks were straightforward, there were few incidents of negative mission awareness.

Following are some examples of statements that indicate good or poor situation awareness in each of the categories:

> ***Location***: An example of when an operator lacked awareness of the robot's location can be inferred by his statement of "OK, the problem with going down a dead end is you're not sure where the heck you are." When operators stated, "I've been here before. I'm sure" (and we know they are correct), we coded that statement as a positive awareness of the robot's location.

> ***Activities***: Another operator drove up a pole attached to a platform and the experimenters stopped the robot. The operator asked, "What did I do? Crash him?" While this statement could be construed as a lack of awareness of the robot's surroundings, it also indicated a lack of awareness of the robot's activities.

> ***Surroundings***: An operator in "Safe" mode (a mode designed to slow and stop before bumping into obstacles) couldn't turn right because an obstacle was in the way. While that operator knew that Safe would keep him from running into obstacles, he said, "I don't see where I'm in contact with anything, so it's not clear why I'm having a problem." In other words, he was not aware that his immediate surroundings contained an obstacle. Thus, we coded this statement as indicative of a lack of awareness of the robot's surroundings.

> ***Status***: In a few cases, experiment participants made statements that indicated a lack of awareness of the robot's status. Participant 3 said, "C'mon, I know I can fit through that hole," while being unaware that the robot was in Safe mode and it was hindering him from going through the opening. Positive understanding of robot status was coded when the operator noted that they were in a particular mode that was causing the robot to work the way it was.

> ***Overall mission awareness:*** Finally, there were a few instances in which an experiment participant stated they had lost sight of overall mission awareness. For example, one operator's statement illustrated the cognitive toll that navigation was taking on keeping mission goals in mind: "…now that I've been sitting here driving, I've sort of lost focus on what I'm supposed to be doing, and that is find the victims. I'm just trying to navigate."

A single utterance could be coded as a negative instance of one awareness category but positive for another; for example, an operator may have said, "I know the robot isn't hitting anything, but I'm unable to move." If the robot wasn't hitting anything, this statement would be classified as positive surroundings awareness (verification of the actual robot status was made using videotapes of the robot and of the interface as well as maps created by observers during the runs that noted collisions). If the robot was hitting something, the statement was classified as negative for surroundings awareness, as the operator was unaware of the robot's surroundings. However, in either case, the utterance would be classified for negative status awareness, as the operator did not know why the robot would not move. (In this type of utterance, the most common occurrence was that the operator was unaware that the robot was in a safe mode, which would stop the robot when it was very close to obstacles.)

After coding the SA-related statements by the categories described above, we totaled the statements for each participant and each interface prior to determining the fraction of statements of each type. We worked with percentages of statements instead of raw numbers because some of the runs were shorter than others due to robot or battery failure.

Two researchers coded the statements. To obtain inter-coder reliability, both coded the same two runs and compared results. The Kappa computed for agreement was .79 (.68 after chance has been excluded). We then discussed and resolved the disagreements and, based on a better understanding, we coded the remaining runs.

5. RESULTS AND DISCUSSION

Before providing results of the LASSO analysis, we summarize the results of our previous study [Yanco et al. 2006] in which we looked at specific performance measures. The previous results provide context for the SA analysis results.

5.1 Summary Results from Previous Study

Objective performance measures consisted of percentage of arena covered, number of bumps, and number of victims found. We found a statistically significant difference in the percentage of arena covered: participants covered more area using System A. There was no significant difference in bumps to the front of the robots but there was a difference in bumps to the rear; we concluded that System B's rear-facing camera helped prevent bumps. There was no significant difference in the number of victims found, but we believe the arena was populated with too few victims to have provided for true differentiation of performance.

Subjective measures consisted of probes of user preferences. There were significant differences in users' perceptions of ease of use (System B being easier to use than System A) and helpfulness of controls (again, System B was preferred).

5.2 Results from Current Study

There were 100 utterances recorded for System A and 92 recorded for System B. As discussed above, the utterances were classified as positive, neutral or negative for each of the five categories of awareness: location, activities, surroundings, status, and overall mission (LASSO). Table 1 presents the analysis of the utterances for each awareness category across the total number of utterances made by the participants. We report the positive and negative classifications only, as a neutral classification meant that the utterance did not apply to that awareness type.

Table 1. Comparison of Positive and Negative Statements Regarding Situation Awareness for Two Interfaces

	System A		System B	
Awareness Type	% Positive	% Negative	% Positive	% Negative
Location	15	18	14.1	14.1
Activities	6	3	15.2	1.1
Surroundings	12	21	29.3	23.9
Status	2	6	1.1	9.8
Overall Mission	0	3	0	3.2
Average	7.0	10.2	12.0	10.4

Table 1 shows that the average percentage of negative statements for the two systems is quite comparable. The averages were obtained by dividing the number of utterances classified as positive or negative by the total number of classifications that could be made (5 times the number of utterances). However, participants were more likely to comment negatively on location (27.7% more) and activities (172% more) for System A and more likely to comment negatively on surroundings (13.8% more), status (63.3% more) and mission (6% more) for System B.

While there were more positive statements made on average for System B, it is more interesting to look at the breakdown of these comments. Participants were more likely to make positive statements about location (6.3% more) and status (81.8%) for System A and more likely to comment positively about surroundings (144% more) and activities (153% more) for System B. Neither system received a positive comment for mission awareness.

5.2.1 Location Awareness

With System A's map-centric view, we found that participants made more (6.3%) positive comments about their location than with System B. Since System B could have its map switched off and did not have the capability for landmark marking as System A did, it makes sense that participants would have better location awareness when presented with a full screen map that placed the robot and landmark markings in it. Participants could mark their starting locations and other victim locations, providing visual cues within the map for showing when the robot returned to a location that had been previously visited. Also, having a good understanding of location is consistent with being able to cover more area: knowing where you've been is conducive to understanding where you need to go to explore new areas.

However, we also observed 27.7% more negative comments made about location in System A's interface (18%) than in System B (14.1%). (Overall, the numbers of positive and negative comments were not significantly different: p=.7 for a two-tailed two sample equal variance t-test.) We believe that the difference in negative comments did not occur due to the map presentations, but instead it occurred because of the video differences between the systems. Although location is map-based, participants often noted their location with a comment indicating that they had seen something that they had seen before. So although the map should allow for better absolute localization, participants were aided by the video-centric view in determining which locations had been visited before, resulting in this discrepancy.

These observations show that the map and video are both very important for establishing location awareness when operating a remote robot.

5.2.2 Activities Awareness

The most significant difference was found in the activities category (p=.02 for a two-tailed two sample equal variance t-test); participants had better activities SA with System B's robot. Participants found it easier to be aware of the robot's progress when using the System B robot versus the System A robot. Participants were able to determine the robots' progress—or lack thereof—with greater ease because they could see the environment moving past—or not moving, in the case of stuck robots—more clearly through the well-lit, dual-camera video stream.

Also, some participants glanced often at the laser zoom view in System B's interface and others observed the sonar indicators turning red; these people usually understood when the robot was in close proximity to walls or obstacles and thus when the robot was going to be stopped by the "safe mode" logic. As one participant put it: "Oh, my gosh, I'm stuck. Got red all around me except forward and backwards." Participants using the System A robot were, on the whole, very aware of the blue blocks indicating a 3D map of the environment but did not always trust them because they saw that the robot could go "through" the blocks on occasion.

This observation suggests that awareness of activities is a video-based activity more than a map-based activity. It is easier to observe the lack of movement from a video window than it is from a robot's avatar on a map.

5.2.3 Surroundings Awareness

Participants had greater awareness of surroundings with System B's interface, although the difference is not significant using a two-tailed two sample equal variance t-test (p=.13). Surroundings awareness shows similar numbers of negative comments (21% for System A and 23.9% for System B), but over twice the number of positive comments for System B (29.3%, as opposed to System A's 12%). We believe that this difference can be accounted for by reasons pertaining to differences in video presentation. System B was equipped with a lighting system that could be switched on and off, allowing operators to illuminate their view when the robot entered a dark area. In the words on one participant using System A: "I can't see really with the camera, so I'm trying to move it where I can see something. I think it got zoomed in somehow." This participant could not see the video image well enough to know how far it was truly zoomed in, and was unsuccessful at finding an angle or zoom setting that enabled him to see the environment clearly.

In addition to dark video, participants were hindered by the video presentation in System A. System A's video was often obscured by blue 3D map blocks presented over the video window. "I want to look down there, and those blue blocks are blocking my view," noted a participant. Further, System A's video was sometimes presented at oblique angles to provide cues that the camera was turned to the side. Participants found themselves craning their necks to look at the oblique video presentation, which was skewed to fit in a parallelogram as opposed to a rectangular window. A participant explained, “I keep wanting to bend my head over and look down at the screen.”

Finally, the System B interface also included the option of seeing video from a rear-facing camera, whereas the System A robot had only a single camera. Having the additional camera in back provided for increased awareness of surroundings to the rear of the robot, as evidenced by the smaller number of times operators bumped the rear of the robot against obstacles when using System B versus System A [Yanco, et al., 2006].

5.2.4 Status Awareness

Status awareness was not significantly different between the two systems (p=.28 for a two-tailed two sample equal variance t-test). However, we found 81.8% more positive status comments made for System A and 63.3% more negative status comments made for System B. Status awareness is not based upon map or video display, but must be presented by displaying modes or health measures such as the current battery level. According to this analysis, System A was more effective in the presentation of status information.

5.2.5 Overall Mission Awareness

For both systems, the distributions of positive and negative mission comments are equivalent (using a t-test, p=.91, showing high correlation). Neither system provided any information that could be used to gain mission awareness, which would account for the similar performance. We found no instances of the participants making positive mission awareness utterances; participants would only occasionally note that they had forgotten what they were trying to do. Mission awareness is not helped or hindered by the map- or video-centric views.

5.3 Discussion of LASSO

Developing our SA coding methodology was unexpectedly challenging. Location awareness and surroundings awareness, in particular, were difficult to differentiate before we determined that the former should relate to landmark orientation and the latter to obstacle avoidance. Another breakthrough came when we determined that every utterance should be examined in light of each type of awareness. Accordingly, each utterance was assigned a combination of five positive, negative, and neutral (i.e., not applicable) coding values corresponding to the five awareness categories. Doing so eliminated the need to determine which awareness category was the most relevant type to assign to an utterance: something we found to be very helpful.

One limitation of LASSO is that it depends upon participants being able to verbalize their thoughts while they are performing their primary tasks. Clearly, some people are better at thinking aloud than others. We note, however, that all subjective SA measurement techniques have drawbacks. For example, some people are better than others at gauging their own level of SA: a key ability needed for other techniques such as the Situational Awareness Rating Technique (SART) [Taylor, 1990]. We believe the difficulty of contending with individuals’ differing abilities to think aloud can be mitigated by using LASSO in a within-subjects experiment design. By doing so, the differences in each person’s verbalization style contribute equally to the results for each interface being studied.

6. CONCLUSIONS AND FUTURE WORK

We have found that a map-centric interface is more effective in providing good location and status awareness while the video-centric interface is more effective in providing good surroundings and activities awareness. Neither interface showed an advantage for overall mission awareness. However, when creating systems for remote robot operation, all five types of awareness are required for effective task completion.

The open research problem is to determine how best to combine the map and video information so that both are presented with the importance and visibility needed to support operators performing high-priority tasks. Researchers for both systems studied in this paper have been revising their interfaces based upon the tests described. Our prediction is that each of the separate research streams will start to converge upon interfaces with similar features and layouts after another series of user testing.

Despite the challenges involved in developing the LASSO SA coding methodology, we believe it helped us to take a more in-depth look at how different interface design approaches supported users’ SA needs. By decomposing SA into five components and evaluating interfaces against each of them, we could begin to tease apart the interface characteristics that affect SA.

Every effort should be made to validate a new evaluation methodology prior to its widespread use. Normally, a new technique is validated by comparing its results to that obtained using an older technique. Even the two SA measurement techniques that are most well-accepted, the Situation Awareness Global Assessment Technique (SAGAT) [Endsley 1988] and SART, do not necessarily provide congruent results. Endsley et al. [1998] evaluated the same interface, a system used by pilots to display threats, using both SAGAT (an explicit technique) and SART (a subjective technique). After analysis, they stated that “The subjective assessment of SA derived via SART does not appear to be related to the objective measures of SA provided by SAGAT….This study supports the utility of a test-battery approach for evaluating display concepts.” The authors then discuss the different ways in which each of the SA measurements techniques were useful. Our paper documents a first step in determining the utility of LASSO by characterizing the kind of insights it facilitates. The next step will be the difficult job of comparing LASSO to another subjective measurement technique.

7. ACKNOWLEDGMENTS

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