

# EFFECT OF DISPLAY ICON MODALITY ON SITUATION AWARENESS

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The present study investigated the effectiveness of different icon modalities in supporting situation awareness (SA) when using a densely populated battlefield COP. The MilSTD 2525B symbology was compared to modified versions of this symbology that were either miniature or proportional, and the U.S. Army Research Lab's blobology concepts. ROTC cadets viewed a simulated military advance that displayed each of the four representation modalities with presentation order counterbalanced. At the end of each segment, cadets responded to a rapid battery of questions about their SA using the Situation Awareness Global Assessment Technique (SAGAT). Participants also evaluated the different icon modalities in terms of both user preferences and the icons' perceived utility in supporting SA. Although participants perceived the current MilSTD 2525B representations as easiest for assisting them in monitoring friendly and enemy forces, the objective SAGAT measure showed that SA performance was highest using the proportional icon modality. Results are discussed in the context of designing unit representations to effectively support SA.

## INTRODUCTION

We are living in the midst of a revolution of information technology. With the proliferation of data sources and the increasing digitization of data, operators in many domains are expected to monitor dynamic, constantly updating data from a wide array of sources covering a broad spectrum of operations. This increased information flow is provided to enhance decision-making and human-system performance, yet often, the high flow of data has a deleterious effect on the operator's understanding of the relevant aspects of the situation. The challenges are not simply in learning to physically perform a task and mastering the motor skills required for performance, but rather in perceptual and cognitive task mastery. If we examine research on aviation accidents and performance under demanding battlefield conditions, we see that operators have no difficulty physically performing their tasks, and no difficulty choosing the correct action once they understand the situation, but they struggle with the task of developing and maintaining an understanding of the situation (Brezovic, Klein, Calderwood, & Thordsen, 1987; Jones & Endsley, 1996).

For this reason, researchers are interested in understanding, evaluating, and improving the situation awareness (SA) of individuals. Endsley

(1995a) formally defines SA as "...the perception of the 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" (p36). Thus, SA is comprised of three levels: perception of relevant data or environmental cues (Level 1), comprehension of their meaning in terms of the goals and objectives of the operator (Level 2), and projection of their impact in the near future (Level 3).

The current research focused on the presentation of unit representations (icons) on the digitized Common Operating Picture (COP). A typical battlefield COP presents an image of a very busy, information dense environment. Unit icons are often located so closely together on the display that they overlap, and frequently even occlude one another, increasing the operator's difficulty in rapidly gaining an understanding of the developing situation. In the current research, we compared the effectiveness of current MilSTD 2525B symbology to that of other representation options. This study examined the utility of approaches that do not "declutter" in the traditional sense (i.e., simply eliminating symbols, thus creating potentially hazardous loss of SA). Instead, this effort sought to convey meaning through variable sizes and proportions, or depiction of unit boundaries. Icon modalities investigated were miniature icons

(smaller versions of standard icons), proportional icons (icon size proportional to unit size), and blobs depicting physical unit boundaries, as developed by the U.S. Army Research Lab's Computer Information Systems Directorate (see Figure 1). The goal was to determine if these approaches can retain critical battlespace object location and identity information, while also reducing clutter and adding much needed data on unit relationships and importance.

## METHOD

### Participants

Sixteen United States Army Reserve Officer Training Corps (ROTC) cadets at a major southeastern United States university volunteered for the study. Student ages ranged from 18 to 27 years, with a mean age of 22.8 years. Seven participants had no prior military service. For the

nine participants with military experience, the time in service ranged from two years, five months, to seven years. Four participants were excluded from the analysis as they did not complete all the performance measures.

### Materials

*Biographical Questionnaire* – Relevant biographical data was collected from each participant including information about age, rank, educational background, and pertinent military experience and training.

*Scenario.* Background for the experimental scenario was provided to participants on paper copies of excerpts from a standard format, U.S. Army Operations Order. The 28 minute simulation was presented on a laptop computer with a mouse, and divided into four, seven-minute segments. Icon modality was changed in each segment.

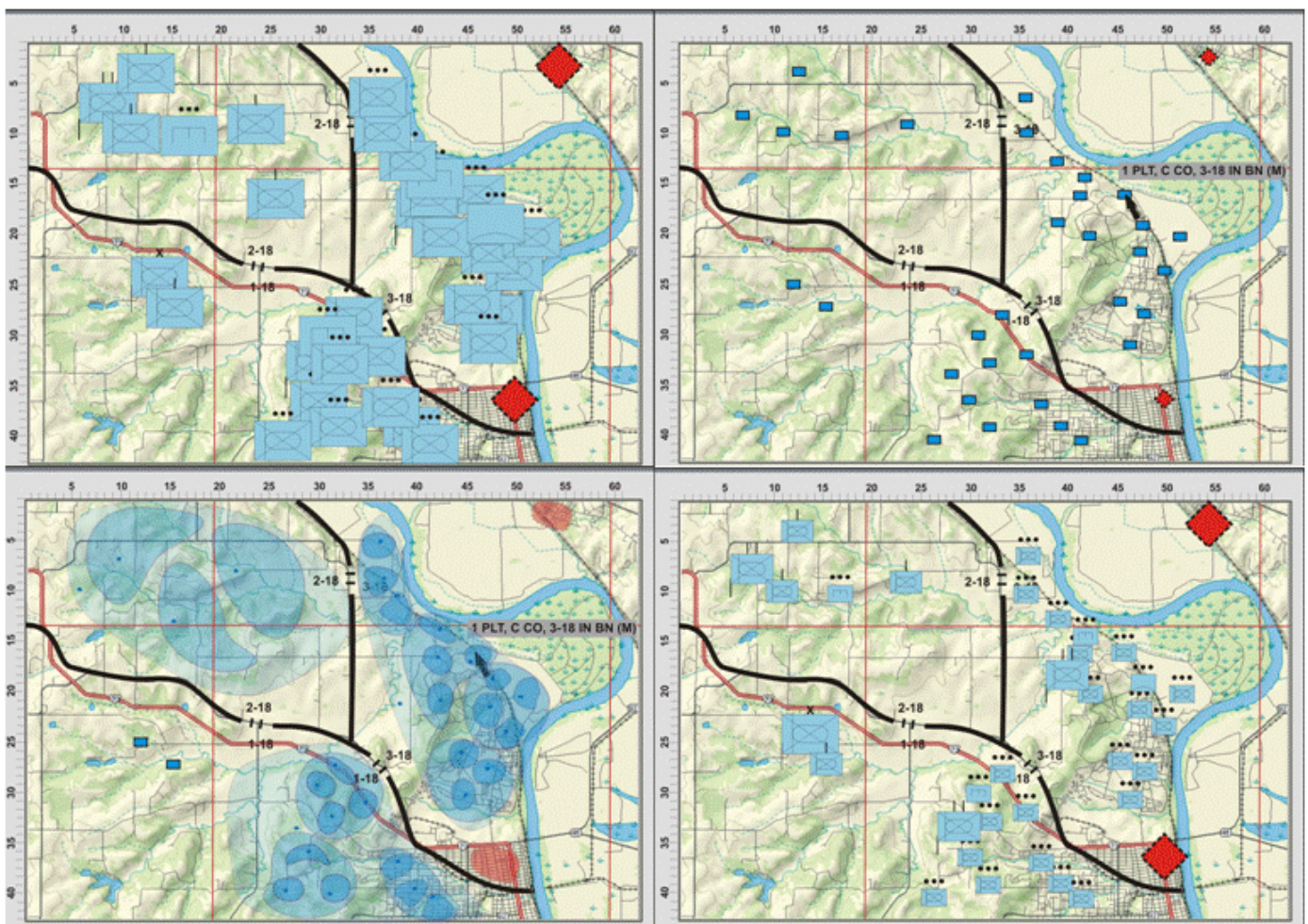


Figure 1. Icon modalities (clockwise from top left): standard, miniature, proportional, and blobs.

*Subjective Assessment of Icon Modalities* – A questionnaire was created to assess participants’ subjective evaluation of the different icon modalities, in general, as well as the icons’ perceived utility in supporting SA. With regard to overall subjective evaluation, participants were asked to specify which modality they liked best and which they liked least. With regard to SA-specific subjective evaluation, participants were asked to specify which modality was easiest for monitoring friendly forces, and which was easiest for monitoring enemy forces.

*Objective Assessment of SA* – The Situation Awareness Global Assessment Technique (SAGAT) was used to objectively measure participant SA during the simulation (Endsley, 1995b). Four freezes were inserted into the simulation, one at the end of each segment, to collect SAGAT data. At each freeze, the simulation was stopped, displays were blanked, SAGAT queries were administered and responses collected electronically. Distinct SAGAT queries were created to specifically assess the three different levels of SA: Level 1 - perception, Level 2 - comprehension, and Level 3 – projection, and a fourth category was included of Level 1–2 status items that asked participants to identify which units were not green on various supply items. Although these can be considered comprehension questions, the information was directly, explicitly provided on the COP.

## Procedure

Each participant completed one scenario trial. Study instructions were provided prior to the trial, including instructions regarding subjective and objective (SAGAT) evaluations. Presentation order was varied between the four segments for each participant using a Latin Squares design. A halt in the action occurred between each segment to collect SAGAT data, and a final SAGAT halt occurred upon completion of the scenario.

## RESULTS

### Subjective Assessment of Icon Modalities

Participant responses are shown in Figure 2. In general, with regard to overall subjective evaluation of icon modalities, more participants preferred standard and proportional icons, although four participants (only one less than the

five who preferred standard and proportional) preferred blobs. Only one participant indicated a preference for miniature icons. Blobs were selected by the largest number of participants as being *least* preferred.

With regard to SA-specific subjective evaluation, more participants indicated that it was easiest to monitor friendly elements and enemy elements in the standard condition.

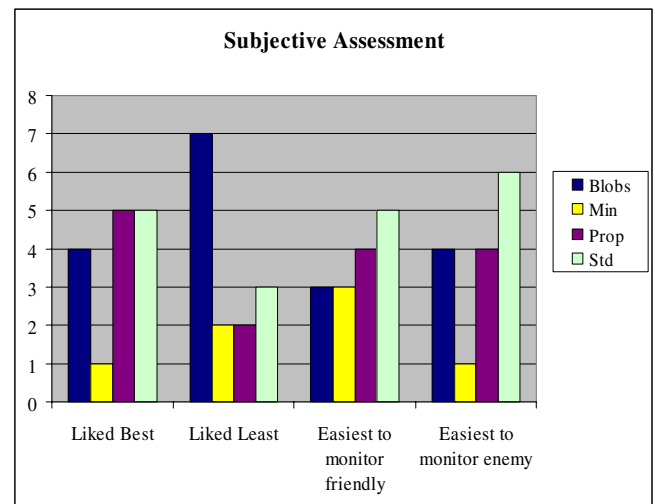


Figure 2. Subjective assessment of icon modalities.

### Objective Assessment of SA – SAGAT

SAGAT data was analyzed using analysis of variance (ANOVA), looking at combined SA for all queries, coupled with an analysis of SA for each level of SA. There was a significant effect of display type for the overall SA score,  $F(3, 42) = 4.430, p < .01$ . Means for overall SA are shown in Figure 3.

Post hoc analysis using Fischer’s PLSD indicated significant differences between individual modalities in some cases. For Level 1 SA, SAGAT performance was significantly different between proportional and standard icons ( $p < .05$ ). For Level 2 SA, proportional and blobs were significantly different ( $p < .05$ ). For Overall SA, significant differences in SAGAT performance were shown between proportional and all other display conditions ( $p < .05$ ). The direction of these differences is shown in Figure 4.

Figure 4 also shows that SAGAT performance was lower for the Level 1 SA queries than for the higher level assessments that come from the lower level data. With the exception of Level 3 SA (a single query on future enemy actions), participant

SA was at least slightly higher in the proportional condition than in all other conditions.

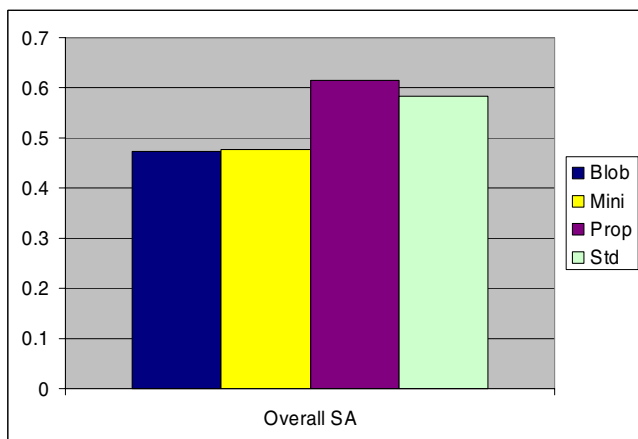


Figure 3. Overall SA across display conditions.

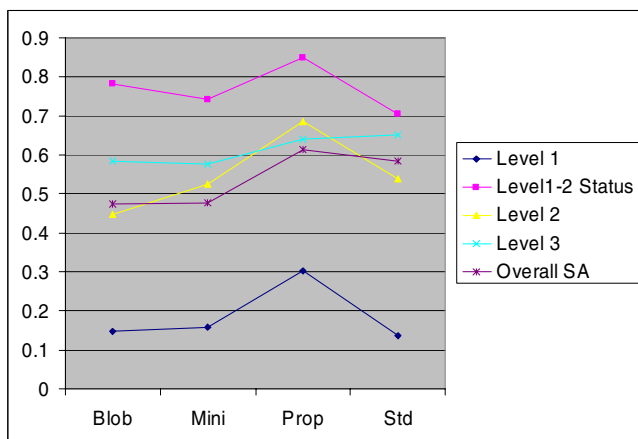


Figure 4. Levels of SA and overall SA for each condition.

## DISCUSSION

In general, participants indicated a slight preference for the current MilSTD 2525B symbology. This icon modality was also favored in the SA-specific evaluation, with participants indicating that it was easiest to monitor both friendly and enemy forces using this display modality. Results from SAGAT, a well-validated objective measure of SA, however, do not support this subjective assessment.

There are several possible reasons for this discrepancy. Participants are likely to have at least some familiarity with MilSTD 2525B icons. Proportional modality was preferred by more people than any modality other than the more familiar Standard modality. Further, SAGAT results indicated that participants were able to answer SAGAT queries more accurately using

this modality. It is not unusual to find indications for a familiarity bias in subjective evaluations.

In addition, some of the screen clutter and occlusion issues this experiment was designed to address may have been actually minimized by the experimental interface, which used concepts of SA-oriented design developed for military operations. Because the experimental display was an individual display, which could be zoomed in or out, issues of screen clutter and stacked icons could be addressed by zooming in to view a smaller area of the map. While this is not an entirely unacceptable solution to the problem, it may increase operator workload due to the dynamic need for resizing the area of interest on the map. Even relatively small increases in operator workload can have a deleterious impact on SA in high demand tasks.

In considering why the proportional condition would provide superior SA for virtually every SAGAT query, we must consider what information proportional icons add to the display. In every respect other than size, proportional icons are identical to standard icons. For the current study, even miniature icons were identical to proportional and standard icons, although the detail on the icons may have been more difficult for participants to distinguish. The only information that is made more salient with proportional icons is unit size. It is possible that by making this information more salient, participants were able to acquire this information with less effort, thus leaving more cognitive capacity for other evaluation tasks.

Finally, the finding that participants scored lower on Level 1 SA data than on higher level assessments that stem from that data likely reflects the specificity of the individual queries. For example, a Level 1 query was *How many companies are currently in contact with the enemy?*, while a related Level 2 query was *Which enemy unit is your most immediate threat?* Although the information in the two queries is somewhat related, there is not a direct correspondence between the two such that the inability to answer the Level 1 query precludes the ability to correctly answer the Level 2 query.

It is important to note that the participants in this study were not all experienced military personnel, and perhaps the findings would be different with active duty personnel intimately familiar with the nuances of MilSTD 2525B. These personnel might initially perform better

with the existing display condition, although early advantages for the familiar system might also be overcome with time.

## CONCLUSION

In general, findings from this study demonstrated that relatively minor design differences can have a significant impact on operator SA. Changing icon size may allow the operator to easily glean valuable information with minimal effort, thus increasing the available cognitive capacity which can be directed toward other tasks.

Results also revealed that operators' subjective evaluations of what design features they believed may support their SA did not necessarily correspond with objective performance measures of SA. Specifically, although participants perceived the current standard iconology as easiest for assisting them in monitoring friendly and enemy forces, an objective measure showed that SA performance was highest using the proportional icon modality. Subjective user evaluations of system or display designs have tremendous appeal, as these are quite simple to develop, administer and analyze. However, as illustrated in this study, design decisions should be based on valid, reliable measures that are more sensitive and diagnostic in detecting the utility of various design features for supporting operator SA.

Finally, future research needs to be conducted with active duty military personnel to determine whether these results can be replicated in a more operationally valid environment. Analysis of subjective workload in each condition would also be valuable in determining whether the improved SA in the proportional condition is truly the result of reduced workload, or whether there are other factors at work.

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