Comparing Levels of Situation Awareness and Digital Proficiency Levels

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ABSTRACT

Evaluating how well a unit employs digital command, control, and communication (C3) systems to support operations adds substantially to the workload of U.S. Army trainers. One means of aiding trainers is to provide observation requirements tailored to fit a unit's estimated digital proficiency level. Digital subject matter experts (SMEs) divided one hundred digital activities into basic, medium, and high digital proficiency groups using a training-oriented definition of digital proficiency (i.e., activities that units are likely to have trouble mastering are addressed at high digital proficiency levels). The purpose of the work described by this paper was to compare the SME-defined proficiency levels with two other definitions of digital proficiency, levels of situational awareness (SA) and progressive skills groups (i.e., one group lays a foundation for the next group). The SA levels, based upon Endsley (1995) are defined as; (1) an accurate perception of the elements of the situation, (2) a comprehension of the situation, and (3) a projection of the current situation into the future. The skills groups were concerned with channeling, managing, assessing, and exploiting information. Each of the one hundred activities addressed by SMEs were rated as to which SA level and which skill group they belonged. The SME-defined digital proficiency levels were correlated with SA levels and with skill groups. Advantages of digital proficiency level concepts that are only mildly correlated with SA levels are discussed.

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Karen Lockaby has over 20 years of experience in Army training development and assessment. She has served in many projects supporting digitization of Army units and is the primary author for the Digital Operating Guide for Brigade and Battalion Staff and the FBCB2 Digital Operators Guide.

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The U.S. Army is applying networked, automated command and control systems in a process referred to as digitization. Digitization enables members of a unit to share mission planning products as they evolve, provides units with improved data on the tactical situation (e.g., global positioning system [GPS]-enabled data on the location of friendly platforms) and analytical tools that enable a greater awareness and understanding of the tactical situation (Barnett, Meliza, and McCluskey, 2001). The U.S. Army Research Institute (ARI) is conducting research and development under the sponsorship of the III Corps Battle Command Training Center and the U. S. Army Training and Doctrine Command on methods of measuring unit employment of digital systems.

Digitization adds substantially to the workload of trainers for unit collective exercise. In addition to addressing the same tactical training objectives applicable to pre-digitized units, these trainers must be concerned with how units employ digital systems to support operations. In the case of the Force XXI Battle Command Brigade and Below (FBCB2) system used on board tactical vehicles, this may include such diverse trainer tasks as checking to see whether vehicle commanders are using the most recent versions of obstacle overlays, finding out if leaders verify they are receiving position location data from all their subordinate FBCB2-equipped platforms, and checking whether leaders manually input icons showing the location of friendly vehicles not equipped with FBCB2 (Leibrecht, Lockaby, and Meliza 2003).

ARI and Northrop Grumman developed the FBCB2 Exploitation Tool as guidance for trainers to use in evaluating the ability of units to employ FBCB2 in the context of collective training exercises. In total, this guidance addresses fifty performance goals for unit application of FBCB2, with most of these goals being associated with multiple measures of performance or diagnostics. One means of helping trainers address the growing workload is to tailor training feedback activities to fit the digital proficiency level of a unit, so that less time is spent trying to observe activities that are easily within or beyond the proficiency level of a unit. Building upon past work, ARI and Northrop Grumman initiated an effort an effort to provide trainers with tools needed to tailor observation activities to fit a unit's estimated level of proficiency in applying FBCB2. The tools included a FBCB2 Proficiency Quick Assessment Guide and FBCB2 Observation Guides tailored to fit basic (B), medium (M), and high (H) levels of unit FBCB2 proficiency.

The FBCB2 Quick Assessment Guide was designed to provide a rapid and inexpensive means of estimating the digital proficiency level of a unit prior to a period of collective training. The guide may be applied by asking questions of key unit members regarding the status of digital Standard Operating Procedures (SOPs) within a unit, the FBCB2 capabilities unit members are likely to employ, and in garrison digital training. Sixty-one statements that may or may not be true of a unit are organized under eleven broad questions such as "how do you ensure your communication network is set up properly," "what actions do you take to ensure your digital information is current and manageable," and "how do you manage the threat picture and relate the threat to your own or unit's location." Each of the sixty-one statements is marked with a "B," "M," or "H" depending upon whether a team of digital SMEs decided the statement notes an activity that should be addressed in basic, medium, or high proficiency exercises. If most of the statements marked with a "B" are not true of a unit, then basic proficiency FBCB2 observation guide should be applied with that unit. If most of the statements marked with an "B" are true of a unit, then it is appropriate to apply the medium or high proficiency guide, depending upon how many of the statements marked with "M" are true of the unit.

A group of Subject Matter Experts (SMEs) with experience training digital units developed FBCB2 Observation Guides for basic, medium, and high levels of proficiency, respectively. The guides were intended to be used in the context of collective tactical exercises to better integrate digital and tactical training. In total, 100 activities were spread among these three guides. SMEs based their decisions about where to assign a particular activity based upon the difficulty of performing the activity combined with the probability

of a unit using specific capabilities (e.g., most digitized units use digital systems to transmit orders and graphics early, but it is rare to find cases where leaders use the circular line-of-sight tool). When identifying the activities to be addressed, SMEs tried to ensure that some of the feedback received even at the lowest proficiency levels would focus on the benefits of employing FBCB2.

Figure 1 illustrates how the activities differ among the three proficiency levels. Figure 2 illustrates what the user of an FBCB2 sees.

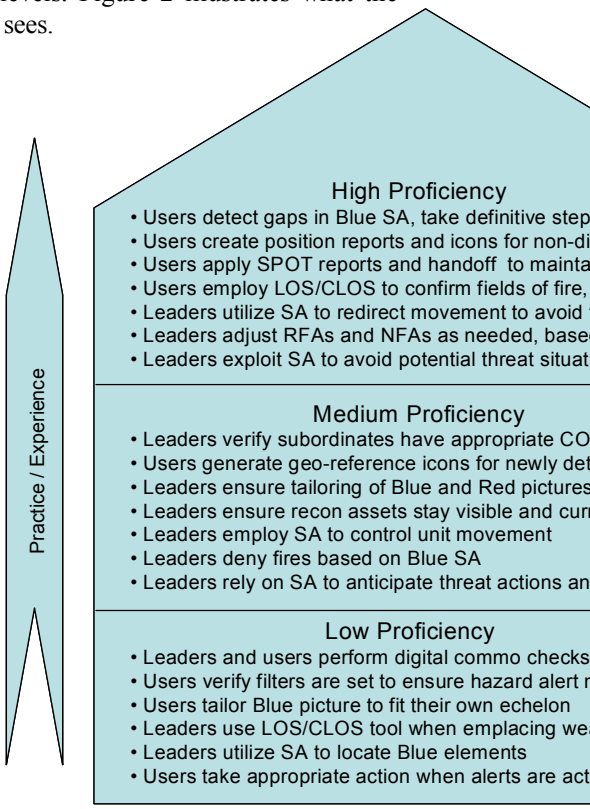

Figure 1. Sample activities addressed within SME-defined proficiency levels.

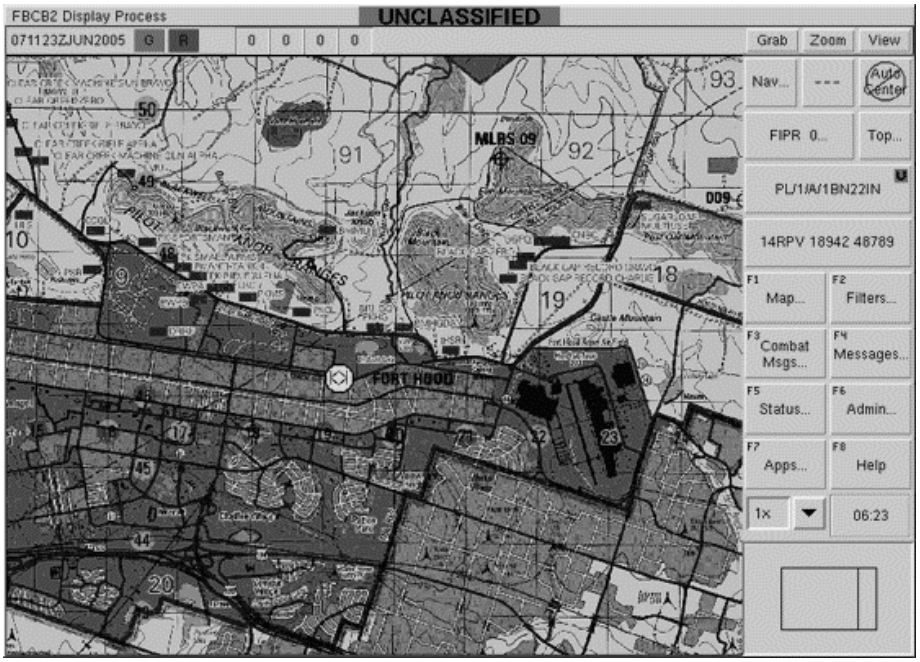

Figure 2. Sample Force XXI Battle Command Brigade and Below (FBCB2) screen.

ARI saw the need to correlate these basic, medium, and high FBCB2 Observation Guides with other possible definitions of digital proficiency levels as one means of validating these lists. Given that improved situational awareness (SA) is one of the major reasons for digitizing the force, the correlation between SME-defined digital proficiency levels and levels of SA was of interest. Another means of validating digital proficiency is to consider that certain activities set the stage for, and enable, other activities. The degree of correlation between SME-defined digital proficiency levels and stage-setting relationships among digital activities is also of interest.

This paper presents our findings about the relationship between SME-defined digital proficiency, SA, and stage-setting relationships among digital skills The first section presents some background on digital command, control, and communication (C3) in the U.S. Army, levels of SA, and stage-setting relationships among digital activities.

BACKGROUND

Digitization

A number of U.S. Army units utilize networked C3 computer systems, known in the U.S. Army as "digital" systems. These computer systems apply automation to help leaders perform many of the C3 functions previously accomplished manually, such as distributing orders and reports, and creating and distributing battlefield graphics.

Information on the tactical situation can be distributed over the network from command centers down to the lowest-level combat formations, which use the information to gain a tactical advantage. Digitization not only increases combat capabilities, but also improves safety by reducing the chances of fratricide or "blue on blue" incidents. In addition, combat units who use digital systems are expected to maintain better SA and to plan and execute operations more quickly than non-digital units (Barnett, Meliza, & McCluskey, 2001).

Digitization serves as a decision-support system for combat commanders. It helps them visualize the battle space and presents needed information format that fosters the commander's SA. Digitization also provides analytical tools, such as terrain analysis tools and automated warnings that can further enhance SA.

Situation Awareness

Early studies of SA were conducted by the U.S. Air Force to enhance combat pilot's ability to understand the tactical situation and use that understanding to win the fight (Fracker, 1991). Situation awareness, according to the U. S. Army Training and Doctrine Command (TRADOC) (1994) is defined as "the ability to have accurate real-time information of friendly, enemy, neutral, and non-combatant locations; a common, relevant picture of the battlefield scaled to specific levels of interest and special needs." SA is recognized as a vital factor in a military leader's ability to gain and exploit a tactical advantage over the enemy. The US Army sees SA as the commander's mental model of the battlefield. Displays like that shown in Figure 2 are often referred to as "SA displays."

However, SA is not confined to the military. SA has been used with pilots, air traffic controllers, fire fighters, and others who are involved in situations that require quick decisions under stress (Gilson, Garland, & Koonce, 1994). It has been examined by a number of researchers, including Endsley, Fracker, and Hartman and Secrist (Garland, Phillips, Tilden, and Wise, 1991). Randel, Pugh, and Reed (1996) studied situation awareness in the context of naturalistic decision-making. They found the ability to make better decisions was based, in part, on better situation awareness. In a similar study, Kaempf, Klein, Thordsen, and Wolf (1996) investigated how SA influences decision-making in a Navy Combat Information Center and found that SA is an important factor in decision quality.

Endsley, who has done considerable research into the nature of SA, theorized a more complex model of SA. Her model suggests SA includes three levels. At the most basic level, an individual perceives the elements of the current situation. At the next level, the individual uses this information to comprehend the situation, and at the highest level, the individual uses this comprehension to predict future events (Endsley, 1995). Thus, a military commander who perceives information about the battlespace would have level one

SA; if the commander is able to comprehend the what the information means, he or she would have level two SA, and if she or he is able to use this comprehension to determine what could happen in the battlespace in the near future, then he or she would have level three SA.

The U.S. Army considers that SA includes information on the mission, enemy, time, terrain, troop, and civilian (METT-TC) situation. To the extent that a unit is aware of the status of each of the METT-TC variables it has the first level of SA. To the extent that a unit understands the immediate implications of these variables, it has the second level of SA (e.g., the lead platoon is being engaged by a large enemy force, and this platoon has access to supporting artillery fires). To the extent that a unit is able to make predictions regarding future tactical events, it has the third level of SA (e.g., a company commander is aware that his lead platoon is about to make contact with the enemy and calls for a smoke mission to obscure the enemy's view).

Stage Setting Relationships

Digital activities appear to fall within four groups defined in terms of the actions performed on digital information. These four groups were initially defined using a top down approach (Barnett, Meliza & McCluskey, 2001). The group names and definitions have been refined through a bottom up analyses that considered hundreds of digital activities. The current list of definitions of the four groups are provide below.

Channel: Make sure connectivity is maintained so information and requests flow across platforms, echelons, and battlefield operating systems.

Manage: Make sure digital information is findable and catches the attention of intended message recipients.

Assess: Assess, and improve upon the currency, accuracy, and completeness of digital information on the tactical situation.

Exploit: Understand the implications of the situation information and exploit digital C3 capabilities to improve tactical performance.

The order in which these groups are listed is important, because groups higher on the list set the stage for groups lower on the list. To the extent that information is not flowing, the stage is not set for managing, assessing, and exploiting information. Poorly managed information is difficult to assess and exploit. Inadequate information regarding the quality and completeness of information makes it difficult to make decisions that exploit this information. On the other hand, knowing how one might exploit digital information should help guide and motivate information channeling, management, and assessment.

These stage setting relationships among skill groups may lead one to expect that the activities addressed in the FBCB2 Observation Guides for units at lower proficiency levels to be more focused on information channeling and management while higher proficiency guides are focused on assessing and exploiting information.

METHOD

The first question of interest was whether digital activities could be reliably assigned to SA levels (1-3) and skill groups (channeling, managing, assessing, and exploiting information). The digital SMEs, applying a consensus approach, assigned each digital activity within each FBCB2 Observation Guide to one of the skill groups. These ratings were compared with a researcher assigned categorization of activities into skill groups. Two researchers independently rated each activity from each level of FBCB2 Observation Guide according to whether it was appropriate to SA level 1, 2, or 3. Ratings were compared for the activities within each of the Observation Guides.

After the percentage agreement was measured, raters discussed discrepancies in an attempt to identify patterns in these differences. For the SA rating, indicators which SME's initially disagreed on were re-rated by having them discuss each indicator and come to a consensus. The final product was a 3 X 3 frequency table showing the number of behavioral indicators in each SA level by digital proficiency level. A similar approach was taken to produce a 4 x 3 frequency table showing the number of activities falling within each skill group by digital proficiency level.

RESULTS AND DISCUSSION

Reliability of Categorizations

Initial inter-rater reliability averaged 84% across the skill group classifications, and 78% for SA ratings. The authors considered this to be acceptable, given the abstract nature of the SA level and skill group concepts.

In terms of SA levels, most of the discrepancies between raters concerned the distinction between the second and third levels of SA, because there is an element of prediction regarding the future even when a

unit responds to the immediate METT-T situation (e.g., if we do not return fire and take cover the enemy will destroy us).

For skill categorization, the distinction between information assessment (and improvement) and either information management or channeling can be confusing for certain applications. The resolution to this problem is to categorize an activity at its highest level (exploit over assess over manage over channel). In terms of both skill group and SA categorization, some of the activities were worded in such a way that they addressed more than one skill group or more than on SA level. Again the resolution is to categorize an activity at its highest SA level or skill group level.

After the initial rating, SME's reached consensus on behavioral indicators all for categories. The raters found that three SA behaviors could not be classified into a single category (i.e., the activities were worded in such a way that they addressed more than one SA level), therefore these behaviors were not included in the two SA analyses. The analysis of FBCB2 Observation Guides by skill groups contained 100 behaviors, while the other two analyses that included SA contained only 97 behaviors.

SA Level	Digital Proficiey Rating			
	Basic	**Medium**	**High**	***N***
1	21 (43%)	15 (31%)	13 (26%)	49
2	7 (23%)	14 (45%)	10 (32%)	31
3	1 (6%)	3 (18%)	13 (76%)	17

Levels of SA

The nature of the relationship between SME-defined digital proficiency levels and SA levels is depicted in Table 1. For each level of SA, the number and percentage of behavioral indicators in the low, medium, and high digital proficiency category is shown. At SA level 1, the greatest percentage of behavioral indicators fell in the low digital proficiency category. For SA level 2, the highest percentage was in the medium digital proficiency level, and for SA level 3, the most behavioral indicators fell in the third, or high proficiency category. Thus, there is a definite positive relationship between digital proficiency and SA levels.

Table 1. **Number (Percent) of Digital Proficiency Indicators at each SA Level**

A two-way Chi-square test was used to identify whether the number of behaviors in each category differed from what could be expected by chance. The results of this test showed there was a significant difference in the number of behaviors in each category, $\chi 2$ (4, N = 97) = 18.05, $p < .01$. This suggests there is a relationship between digital proficiency level and SA level.

To test this relationship, a Cramér Coefficient (C) was calculated. The Cramér Coefficient is a measure of the relationship between two variables based on nominal or frequency data (Siegel & Castellan, 1988), and is often used in conjunction with Chi-square tests. The results of the C test are interpreted similar to a correlation coefficient, in that values closer to zero are interpreted as less of a relationship and values closer to one are interpreted as a stronger relationship (Siegel & Castellan, 1988).

The results of the Cramér Coefficient was C = .305, which suggests a small to moderate relationship between digital proficiency levels and SA levels. Since the Cramér Coefficient is based on a Chi-square test, the confidence level for this test is the same as the Chi-square (Siegel & Castellan, 1988), above, which was $p < .01$.

First level SA activities are found even at the higher levels of FBCB2 proficiency. This is due to the fact that it is comparatively difficult to ensure the tactical METT-TC elements are accurately reflected in digital displays. At higher levels of digital proficiency units are still learning how to incorporate and update position location data for non-digitized friendly forces and civilians. They are also learning how to hand off responsibility for monitoring and updating information on the location of threat forces, how to provide improved information on the terrain situation, and how to provide improved information on the location and capabilities of logistical assets.

If the SME-defined skill proficiency levels had been designed to correlate perfectly with SA levels, the units at the lowest level of proficiency would not be reaping any of the benefits of digitization. Instead, these units would be learning how to improve upon the information about the tactical situation available in SA displays rather then being trained to take advantage of this information to increase combat effectiveness.

Skill Groups

An examination of Table 2 shows how skill groups and digital proficiency ratings are related. For the channel and manage skill groups, the greatest percentage of indicators are at the low proficiency rating, while the greatest percentage of the assess group are at the medium rating, and the greatest percentage of

behavioral indicators for the exploit skill group are in the high rating. It is fairly clear from this pattern that as digital proficiency increases, skills migrate from channel, to manage, to assess, to exploit skill groups.

Skill	Situation Awareness Level			
	1	2	3	*n*
Channel	17 (100%)	0 (0%)	0 (0%)	17
Manage	21 (68%)	6 (19%)	4 (13%)	31
Assess	10 (91%)	1 (9%)	0 (0%)	11
Exploit	1 (3%)	24 (63%)	13 (34%)	38

The same statistical tests used to examine SA levels as a function of SME-defined FBCB2 proficiency levels were used to examine skill groups. The initial Chi-square test contained a number of cells (greater than 20%) whose expected frequency was less than five, which violates the assumption of the Chi-square. Therefore, the "assess" and "exploit" categories were combined, since the "assess" category had relatively few behaviors and these two categories are closely related. This increased expected cell frequencies so that no cells had an expected frequency of less than five.

The Chi-square analysis showed the pattern of behaviors differed significantly from chance; $\chi 2$ (4, N = 100) = 14.35, $p < .01$. The results of the Cramér Coefficient was C = .267, which suggests a small to moderate relationship between skill groups and digital proficiency.

Skill Group	Digital Proficiency Rating			
	Low	Medium	High	*n*
Channel	8 (45%)	4 (22%)	6 (33%)	18
Manage	14 (45%)	11 (36%)	6 (19%)	31
Assess	2 (18%)	5 (46%)	4 (36%)	11
Exploit	5 (13%)	13 (32%)	22 (55%)	40

Table 2. Number (Percent) of Digital Proficiency Indicators for each Skill Group

The last analysis compared skill groups to SA levels. Table 3 shows the number and percentage of behaviors in a skill group at each SA level. All of the behavioral indicators in the channel skill group were rated as SA level 1. The largest portion of behaviors in the manage and assess skill groups were at SA level 1, followed by SA level 2 and then SA level 3. The exploit skill group only had one behavior rated as SA level 1, while the bulk of the behaviors were rated as SA levels 2 and 3.

Table 3. Number (Percent) of Situation Awareness Level Indicators for each Skill Group

The Chi-square showed it was highly probably the pattern of behaviors was not due to chance; $\chi 2$ (4, N = 97) = 35.87, $p < .01$. The Cramér Coefficient was fairly high; C = .43, showing there is a fairly strong relationship between skill groups and SA levels.

Significance of the Statistical Analysis

The associations between SA levels and digital proficiency levels (C = .305), and between digital proficiency and skill groups (C = .267). are small to moderate but, none the less, significant. Likewise there is a moderate association between skill groups and SA levels (C = .43). Again, if the correlation between SME-defined digital proficiency levels and either SA levels or skill groups were too high, then units at lower levels of proficiency would be too focused on improving digital information at the expense of using this information to support operations.

Relevance of Findings to SA Theory

The application of digital C3 systems leaves an audit trail that can be used to better understand and measure the three levels of situational awareness proposed by Endsley (1995). Thanks to digital SA displays and tools there are now external correlates of cognitive events associated with the levels of SA. Units must take actions to progress through levels of SA, and these actions leave an audit trail in the digital C3 environment.

At the first level of SA, one can observe what is being done to improve upon unit awareness of METT-TC situation variables. For example, are the locations of all FBCB2-equipped shown in SA displays as part of the friendly picture, and has the unit added the location of friendly units not equipped with FBCB2 to SA displays.

In terms of the second level of SA, digital C3 systems continue to provide external correlates of cognitive events. Digital C3 systems can examine data on the tactical situation, "understand" the implications of the situation, and alert units to their findings. For example, FBCB2 has the capability to monitor the location of a platform relative to threat situations (e.g., minefields) and warn the vehicle commander when the platform approaches these threat situations. To reap these benefits, the platform commander must set the

alarms and post overlays depicting threats. A platform commander or higher unit leader may also use SA displays to track friendly locations relative to threat situations, without the benefit of automated alarms.

The highest level of both SA and digital proficiency is when individuals are able to project their situation understanding into the future and use it to plan their actions. Leaders and soldiers can plan their maneuver, not on what the enemy is doing now, but what they will be doing when the two forces come in contact. Again, much of this prediction activity leaves an audit trail in the digital C3 environment. In many cases, unit members may be employing line-of-sight tools and other analytic tools to help predict future events. Conveying the results of these analyses to others adds to this audit trail.

As previously noted in this paper, the lack a perfect relationship between SME-defined levels of FBCB2 proficiency and levels of SA is due, in part, to the work required to include and update information regarding the status of METT-TC situational variables. The SME-defined levels of proficiency provide a training-oriented definition of proficiency (activities that are easier to train are addressed at lower levels of proficiency). Certain of the actions required to maintain the first level of SA are difficult to learn and are therefore addressed at higher levels of FBCB2 proficiency.

It is important to note that a unit does not necessarily need to have complete first level SA regarding any of the METT-TC variables before it has second level SA regarding the tactical situation. For example, SA displays may lack information regarding the location of certain friendly vehicles, as well as other METT-TC variables, and still provide enough information to help a unit understand the implications of a situation. For example, a particular SA display may show the locations of only half the friendly elements in a unit. In a situation where a commander sees a potential target, notes the target is at the same location as one of the few friendly platforms depicted in the SA display, and decides not to fire, the commander would have correctly interpreted a situation and avoided a fratricide.

SUMMARY

This research provides a validation for the SME-developed levels of digital proficiency reflected in the basic, medium, and high proficiency level FBCB2 Observation Guides. The activities addressed within these guides are correlated with levels of SA, and they are correlated with a progressive sequence of digital skill groups. Efforts are under way to continue the validation process through trial application of the Quick Assessment Guide and Observation Guide to the training of U.S. Army units.

The research also considered why SA levels do not correlate perfectly with SME-defined levels of digital proficiency. Substantial work is required to ensure certain elements of the METT-TC situation are accurately depicted in SA displays. For this reason, even units that have reached a high level of digital proficiency are expected to have difficulty maintaining an accurate representation of all aspects of the METT-TC situation. On the other hand, even a partially complete picture of the situation can enable a unit to understand the situation enough to pick an enlightened course of action and to prepare and prepare for major tactical events.

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