Current and Future Net-Centric C3: Usage and Preferences

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ABSTRACT

Net centric command, control, and communications (C3) is an important part of current military operations. As the current force moves towards the future force in the form of Future Combat Systems (FCS), net centric C3 will become even more valuable. This research sought to extrapolate net centric C3 usage trends from the current to the future force. To do this, two similar studies were compared. One study asked Soldiers with Army Battle Command System (ABCS) digital C3 systems experience in real-world deployed operations about how they employed these systems, and the second asked similar questions of Soldiers conducting research in an experimental future force C3 simulator designed to explore FCS concepts. Participants were given lists of digital C3 functions common to both ABCS and the future force simulator and asked to rate whether they preferred to perform the functions digitally or manually, how frequently they used each function, how difficult it was to learn how to use the function, and how difficult it was to use the function. The comparison of these two groups showed there are a number of similarities between current and extrapolated future usage patterns, but also some differences. Leaders and Soldiers in the future force simulator preferred using digital methods to perform more C3 functions, and said they performed those functions more often than Soldiers using current ABCS systems. The research also found a number of C3 functions were easier to learn and use in the future force simulator versus current ABCS systems. The results suggest digital C3 systems will be better utilized and more preferred as they become more interoperable. This knowledge can be used to help further develop future systems and design future training programs.

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Military command, control, and communication (C3) has moved into the computer age. Typical C3 products, such as reports, orders, battlefield graphics, and planning products that were once transmitted by telephone, radio, and runner can now be distributed digitally over a computer network. Digital, networked C3 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).

Networked digital C3 is helping to integrate units and formations more closely together. In the future larger formations and even different services will be able to share information more easily and integrate their actions more closely. Digital C3 is helping the military move toward the vision of "one team, one fight."

If future C3 continues to rely more and more on networked computer systems, how will this affect the way C3 is performed? Will basic C3 principles remain the same, or will they change drastically?

The present research sought to provide some initial answers to these questions by comparing two experiments. The first experiment asked Soldiers who use current Army Battle Command Systems (ABCS) to rate a number of C3 functions which can be performed using ABCS. They were asked to rate the functions as to whether they preferred to use digital means or traditional non-digital means to perform each function, how often they performed each function, how hard it was to learn the function, and how hard it was to perform the function. The second experiment asked similar questions of Soldiers using a future force C3 simulator designed to explore Future Combat Systems (FCS) concepts.

The next section will briefly discuss digital C3 and future force C3, followed by a description of experiments one and two. The final section will present the results of the comparison of these two experiments and discuss the implications of the findings.

Digital C3

The U.S. Army has fielded networked, computer-based command and control systems in a process referred to as digitization. These systems employ computer automation to help leaders and Soldiers perform many of the C3 functions previously accomplished manually, such as planning missions, creating and distributing battlefield graphics such as map overlays, and distributing orders and reports.

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 situation awareness (SA) and to plan and execute operations more quickly than non-digital units (Barnett, Meliza, & McCluskey, 2001).

Digital C3 serves as a decision-support system for combat commanders. It helps them visualize the battle space and presents needed information in a 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.

There are a number of different digital systems. Many of the systems are specific to certain Battlefield Functional Areas (BFAs) such as Intelligence, Maneuver, Field Artillery, Air Defense, and Combat Service Support. These systems were designed to fulfill C3 functions related to the BFAs and are typically located in Tactical Operations Centers (TOC) at higher echelons. Although these systems were originally designed to operate within the BFA, they are able to share most information with other BFA systems on the network.

The Force XXI Battle Command, Brigade and Below (FBCB2) is a digital C3 system designed for lower-echelon maneuver units and is typically located in vehicles such as tanks and infantry fighting vehicles, as well as lower-echelon TOCs. FBCB2 allows lower

echelon units to plan missions and routes, and develop battlefield graphics such as obstacle overlays.

Once the mission is executed, leaders and Soldiers can follow the progress of the mission on the FBCB2 display (Figure 1). Vehicle-mounted FBCB2s can automatically update the vehicle's position using a Global Positioning System (GPS) position. The vehicle's position is periodically updated and transmitted to the network, so that the FBCB2 display shows the vehicle's own position as well as the positions of other vehicles in the unit. This allows leaders and Soldiers to develop sound awareness of the friendly situation. In addition, when enemy units are reported on the network through SPOT reports, their positions are displayed as well.

Digital C3 is an evolving concept, and the U.S. Army continues to develop doctrine, tactics, and procedures to exploit its advantages. However, the U.S. Army is also looking forward and investigating future force C3.

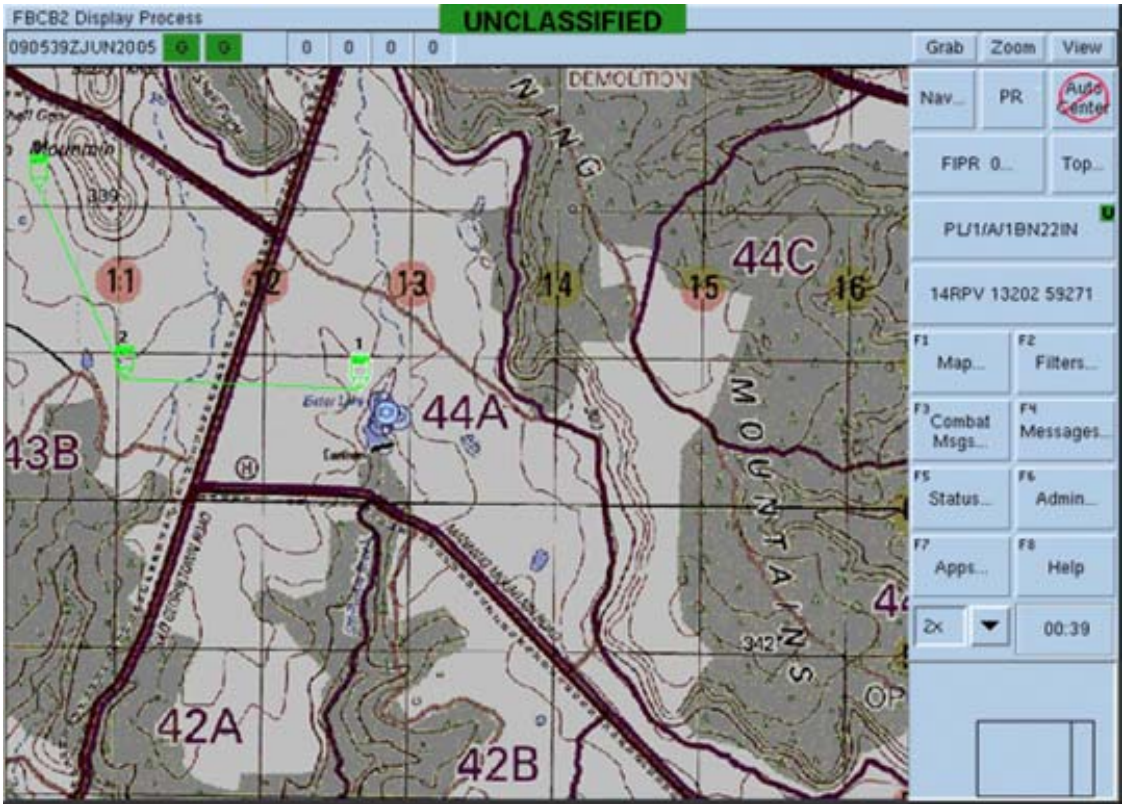

Figure 1. Example of FBCB2 Display

Future Force C3

Experiments are currently underway to determine the nature and structure of the future force and future force C3. The Defense Advanced Research Projects Agency (DARPA) is sponsoring a program to develop an advanced C3 system that integrates multiple BFAs within a single interface. The object is to have a system that is fully collaborative across echelons within a networked environment to enhance a commander's decision-making processes.

DARPA is utilizing a family of experimental simulators in their MultiCell and Dismount C2 (M&DC2) program which is designed to explore FCS concepts. M&DC2 is being used to experiment with a new approach to battle command, which will provide dynamic planning, and rapid mission execution capability. This new approach will facilitate decision making among multiple Combined Arms echelons, Higher Headquarters, Joint Forces, and Dismounted assets. It will do this by integrating advanced decision aids and battle command tools with a supporting knowledge base (Defense Advanced Research Projects Agency, n.d.). Figure 2 shows an example of a simulated future force C3 vehicle.

Gumbert, Cranford, Lyles, and Redding (2003) discussed some of the differences between current ABCS C3 systems and projected future force C3. The most salient difference is that future force C3 will be a single, integrated system that performs all of the C3 functions that now require multiple systems. This should streamline C3 by eliminating the necessity to manually process information to convert it into a form comprehensible by other digital systems.

Figure 2. Simulated Future Force C3 Vehicle

In addition, a greater reliance on automation will help reduce the amount of information processing currently required to translate data into information useable by commanders. The vision is for a Commander Support Environment (CSE) employing a single graphical user interface to present all battlefield relevant information in a format that facilitates decision making (Gumbert, et al., 2003).

ABCS is the current digital C3 system, while M&DC2 is an extrapolation of future force C3. A comparison of these two systems can provide insight into the nature of C3 of the future.

EXPERIMENT 1

The first experiment involved Soldiers using current ABCS digital systems. The Soldiers were given a set of questionnaires that assessed how they used these digital C3 systems in an operational environment.

Participants

Eleven Soldiers who were familiar with using a variety of ABCS systems participated in experiment one. Most were veterans of Operation Iraqi Freedom (OIF) and had used ABCS systems in a combat environment. They had between one and 12 years of service (M = 4.8, SD = 3.43) and ranged from Specialist/Corporal (E4) to Captain (O3).

Six of the 11 reported having attended formal training on ABCS, while the others reported learning to use the systems through on-the-job training or watching others. They had been assigned to echelons ranging from platoon through corps.

All but one participant reported owning a personal computer (PC), and all who owned a PC reported they had Internet access. They stated they operated a computer an average of 15.9 hours a week (SD = 7.9). All claimed to be familiar with at least one common office software package. When asked how often they used common office software (Word, Excel, Powerpoint, etc.) 55% responded "occasionally" or "fairly often" while 45% responded "all the time." Respondents all reported playing computer games.

Apparatus

The apparatus for this experiment consisted of a set of two questionnaires, one for users of Force XXI Battle Command, Brigade and Below (FBCB2), a maneuver-unit level digital system, and one for users of digital systems normally found in Tactical Operations Centers (TOC). Both questionnaires asked similar questions about how Soldiers used features of the digital systems. The FBCB2 questionnaire asked additional questions about features specific to FBCB2.

The questionnaires were developed with the assistance of Subject Matter Experts (SMEs) and instructors from the U.S. Army III Corps Battle Command Training Center (BCTC) at Fort Hood, Texas. The instructors and experts compiled lists of common C3 tasks that could be performed on digital C3 systems and also developed questions regarding how Soldiers employed the systems.

The questionnaires provided a list of generic functions that could be performed on the digital C3 systems and asked Soldiers whether they preferred to perform the function digitally or manually, how often they used the function, how difficult is was to learn to use the function, and how difficult it was to use the function. There were a number of functions common to both TOC digital systems and FBCB2, but there were also functions specific to each of these systems. In all, the questionnaires asked about 38 functions; 23 were common to all systems, seven were TOC only functions, and eight were FBCB2 specific functions.

Procedure

Participants who had experience with only the FBCB2 system were given the FBCB2 questionnaire. Participants who had experience with one or more TOC system were given the TOC questionnaire.

EXPERIMENT 2

The second experiment was similar to the first in that Soldiers were given questionnaires to asses how they used digital C3 systems in this case. Soldiers received one questionnaire when they had finished M&DC2 training and a second, similar questionnaire after the M&DC2 experiments were complete.

Participants

For experiment 2, 17 participants responded on the first (post-training) questionnaire; however, only 13 responded on the second (post-experiment) questionnaire. Eleven of the participant Soldiers had less than five years of service, two had between five and nine, and three had 10 or more years (M = 4.2, SD = 4.98). Five Soldiers had used digital C3 systems before. Twelve Soldiers said they owned personal computers. Eleven of these computer owners had an internet service provider. All but one of the respondents said they used common office software at least occasionally, and all had used gaming systems.

Apparatus

The two versions of the questionnaire (post-training and post-experiment) were basically identical, except that the first administration also included demographic questions. The questionnaires asked questions similar to those in experiment 1.

Procedure

The questionnaire was administered twice, once at the end of the training period, and once at the end of experimentation.

RESULTS

There were 23 digital C3 functions that were common to both ABCS and M&DC2 (see Table 1). Between the two experiments, there were essentially three data sets; the ABCS questionnaire from experiment 1, the M&DC2 post-training questionnaire, and the M&DC2 post-experiment questionnaire, both from experiment 2. Soldier ratings of the digital functions were compared for the three data sets.

Unfortunately, there were relatively few Soldiers who participated in experiment one. Although a much larger number of respondents were planned (80), the current operations tempo in the U.S. Army means that experienced Soldiers have many higher priority taskings. Therefore only 11 Soldiers were available for experiment one. For experiment two, 17 Soldiers participated in the M&DC2 experiments and all 17 were asked to participate by completing a questionnaire.

For the majority of the analyses, modes were used rather than means. The mode is the score that occurs most often in a group of scores. In some cases, the ratings of one or two Soldiers were significantly different from the majority of Soldiers' ratings, which tended to skew the mean. Therefore, the mode was chosen as being most representative of the opinion of the majority of Soldiers. In the few instances were the results were bimodal, means were used.

Digital Preference

The first question asked the participants to rate the digital functions as to whether they preferred to use digital (i.e. ABCS or M&DC2) systems to perform the functions or some other non-digital means, such as using a map board, radio, etc. Due to an error with one of the questionnaires, only 17 of the 23 functions listed in Table 1 were able to be rated for digital preference.

Table 1. Digital Functions Rated by Soldiers

Send/Receive Information
Create/send/receive reports
Create/send/receive orders
Create/send/receive graphics/overlays
Create/send/receive free text messages
Report logistics status
Report personnel status
Planning Functions
Perform terrain analysis
Check trafficability of routes
Develop plans and orders
Coordinate plans and orders
Distribute plans and orders
Synchronize tasks between units
Synchronize support actions
Manage logistics
Manage personnel actions
Situation Awareness Functions
Check location of friendly units (from your unit)
Check location of friendly units (from other units/allies)
Check location of civilians
Check location of enemy units
Check location of obstacles
Check location of other areas of interest (not covered above)
Use reminders
Check that units are following plan/branches/sequels

There were two questions to answer regarding digital preference. First, is there a difference between ABCS Soldiers' preferences for digital use and M&DC2

Soldiers' preferences? Second, if there was a difference in ratings, how were those differences characterized?

To find out if there was a difference between ABCS and M&DC2 Soldiers' digital preference scores, we performed a Chi-square analysis. A Chi-square test is used when objects or scores fall into a number of different categories. It tests the probability that differences in the number of objects or scores in the categories are due to something other than random chance. If the calculated probability (p value) is less than the chosen level of significance (in this case $p < .05$) then the differences are probably not due to chance, but can be attributed to another factor.

To perform this analysis, the number of times a group of Soldiers chose digital preference for a function was added together for all functions, and the number of times the group chose manual preference was added together for all functions. This was done for each group; ABCS, M&DC2 post-training, and M&DC2 post-experiment Soldiers.

The result was a table (the Chi-square contingency table) with the total number of digital preference for all functions and the total number of manual preferences for all functions for each group. Table 2 depicts the Chi-square contingency table to clarify how these data were compared.

Table 2. Chi-Square Contingency Table for Digital Preference of all Functions

	Number of Digital Preference Ratings	Number of Manual Preference Ratings
ABCS	86	56
M&DC2 Post-Training	191	50
M&DC2 Post-Experiment	160	30

Two sets of Chi-square analyses were accomplished. The first was an overall analysis that tested all three groups of Soldiers together to determine if there was a significant difference between any group. The results of this analysis showed there was a significant difference in preference ratings between ABCS, M&DC2 post-training, and M&DC2 post-experiment data ($\chi^2 = 27.16$, $df = 2$, $p < .001$).

Once the overall analysis indicated a significant difference, the second set of tests were post-hoc analyses which compared each group against the other two to determine where these differences lay.

Post-hoc analyses showed a significant difference between ABCS and M&DC2 post-training ratings ($\chi^2 = 15.59$, $df = 1$, $p < .001$). There was also a significant difference between ABCS and M&DC2 post-experiment ratings ($\chi^2 = 23.68$, $df = 1$, $p < .001$). However, when M&DC2 post-training and post-experiment ratings were compared, no significant difference was found ($\chi^2 = 1.7$, $df = 1$, *n.s.*).

Once we found differences between ABCS and M&DC2 digital preference ratings, the next step was to determine the nature of those differences. To do this we calculated the ratio of digital versus manual preference responses as a percentage of total responses for each of the 17 functions. We identified those functions where more than 50% of the Soldiers in a group preferred digital means (digital preference functions) for both ABCS and M&DC2. ABCS Soldiers preferred to use digital means for 11 functions (65%), M&DC2 Soldiers preferred digital means for all 17 functions (100%) post-training, and for 16 functions (94%) post-experiment.

Next, we identified how many functions had a greater than 10% difference in rating between ABCS and M&DC2 Soldiers. We found Soldiers using M&DC2 had a greater preference for digital usage for 10 (59%) of the functions post-training, and 13 (76%) of the functions post-experiment. In every case where there was a significant difference in ratings, M&DC2 Soldiers had a greater preference for using digital means to perform a function than ABCS Soldiers.

Three functions had high scores for all three ratings. Between 86% and 92% of the Soldiers in all groups preferred to use digital means for "Create / send / receive graphics and overlays," between 90% and 94% preferred digital means for "Check location of friendly units (from your unit)," and between 90% and 100% preferred digital for "Check location of friendly units (from other units / allies)."

Frequency of Use

Participants were next asked to rate the 23 functions shown in Table 1 as to how frequently they employed them. The functions were rated on a four-point scale, from (1) "never used it," to (2) "used it occasionally," to (3) "used it often," to (4) "used it most of the time." Modes were calculated for ABCS, M&DC2 post-training, and M&DC2 post-experiment ratings and compared.

When ABCS ratings were compared with M&DC2 post-training ratings, 10 functions were rated as more frequently used by M&DC2 Soldiers and three functions were rated as less frequently used by

M&DC2 Soldiers. The remaining 10 functions were rated the same for ABCS and M&DC2.

However, when ABCS ratings of frequency of use were compared with M&DC2 post-experiment ratings, all 23 functions were rated exactly the same by both groups. Three functions; "Create / send / receive graphics / overlays," "Develop plans and orders," and "Determine location of friendly units (from your unit)" were used "most of the time." One function; "Create/send/receive reports" was rated as being used "often," and three functions; "Create / send / receive free text messages," "Determine location of friendly units (from other units / allies)," and "Determine location of other areas of interest" were used "occasionally." The remaining functions were rated as being rarely used.

Difficulty Learning to Employ a Function

Soldiers rated each function as to how difficult it was to learn to employ the function. The rating scale asked them to rate whether it was (1) "Very easy," (2) "Easy," (3) "Somewhat hard," or (4) "Very hard" to learn to use the function.

Comparing the ratings of ABCS Soldiers with M&DC2 Soldiers after training, M&DC2 Soldiers rated three (13%) of the functions more difficult to learn, 14 (61%) easier to learn, and six (26%) the same as ABCS Soldiers' ratings. When ABCS ratings were compared to M&DC2 Soldier's ratings after the experiment was complete, M&DC2 Soldiers rated two functions (9%) more difficult, 17 (74%) easier, and four (17%) about the same to learn.

For M&DC2 Soldiers, two functions, "Coordinate plans and orders" and "Develop plans and orders" had higher learning difficulty ratings than ABCS both after training and after the experiment was complete. One function, "Synchronize tasks between units" was initially rated harder to learn by M&DC2 Soldiers after training, but after the experiment was complete, they rated it easier than ABCS Soldiers rated the function.

The greatest disparity in ratings occurred between three functions. "Create / send / receive overlays," "Manage logistics," and "Check that units are following plans / braches / sequels" were all rated as "Somewhat hard" to learn by ABCS Soldiers, but "Very easy" by M&DC2 Soldiers.

Difficulty Performing a Function

The last question asked Soldiers to rate each function as to how difficult it was to perform, using the same four-point rating scale used for the previous question. One function, "Check that units are following plans / branches / sequels" was not rated by ABCS Soldiers, so only 22 functions were compared for this question.

Comparing ABCS ratings with M&DC2 post-training ratings, M&DC2 Soldiers rated 14 functions (64%) easier to use, eight functions (36%) of similar difficulty, and no functions more difficult than ABCS Soldiers' ratings. After the M&DC2 experiment was complete, M&DC2 Soldiers rated 20 functions (91%) easier, two functions (9%) of similar difficulty, and no functions more difficult than ABCS Soldiers' ratings.

When M&DC2 post-training and post-experiment ratings were compared, M&DC2 Soldiers rated 13 functions (57%) easier, six (26%) the same, and four (17%) harder after the experiment than they had rated them after training. It is interesting that the Soldiers found four functions harder to perform after employing them during the experiment than they had expected after training. These four functions are; "Check location friendly units (from your unit)," Check location of friendly units (from other units / allies," "Check location of civilians;" and "Check that units are following plans / branches / sequels."

DISCUSSION

These results provide evidence that Soldiers prefer to use digital tools to perform C3 functions and suggests that this trend will increase in the future as FCS is fielded.

The analysis of Soldier's preference for using digital systems to perform C3 functions shows that future force (i.e. M&DC2) Soldiers had a greater preference for using digital means than current (ABCS) Soldiers. There was a difference in ratings between ABCS and both M&DC2 data sets, but not between M&DC2 post-training and post-experiment data sets. Although the two groups of Soldiers were different, this suggests that the differences shown were due to the systems used and not due to some other factor. Also, digital preference ratings for both M&DC2 data sets were consistently higher than ABCS ratings, which provide strong evidence that future forces will rely more heavily on digital means to perform C3 functions.

The results also suggest which C3 functions will continue to be important in the future. Functions involving visualizing the battlespace and maintaining situation awareness, such as checking the location of friendly units, enemy units, and civilians, as well as using battlefield graphics, will continue to be important. Determining the location of friendly units, both from the Soldier's own unit and also other units and allies, as well as creating and sending overlays, was highly preferred by both ABCS and M&DC2 Soldiers. These functions were also used frequently by both groups of Soldiers.

In addition, functions involving the distribution and management of information, such as distributing reports and graphics will also maintain their importance as C3 tools. Reporting functions had high scores both for digital preference and for frequency of use.

Amazingly, once M&DC2 Soldiers gained experience with the M&DC2 system, their ratings of the most frequently employed functions matched the ABCS Soldiers' ratings exactly. Both groups chose seven functions as being employed "occasionally" or more often. Table 3 lists the most employed functions agreed upon by both ABCS and M&DC2 Soldiers.

The results on frequency of use of the various digital functions give us an idea of the types of digital C3 functions that are used most often, and are presumably most useful. However, the reader is cautioned that the converse is not necessarily true. This does not mean that those functions that were used less often are not useful. While some functions are relevant to most situations, some functions are specific to particular situations and therefore may not be used as often in different circumstances. For example, peacekeeping and stability operations rarely call for massed artillery fire, so that the "call for fire" function may not be employed very often, if at all. However, in a theater conflict against an organized enemy force, artillery may be employed frequently, and the "call for fire" function may have a very high frequency of use. Thus, frequency of use for some functions is often dependent upon the situation.

Table 3. Functions Most Frequently Employed by Both ABCS and M&DC2 Soldiers

Function	Frequency of Employment
Create/send/receive graphics/overlays	Most of the time
Develop plans and orders	Most of the time
Check location of friendly units (from your unit)	Most of the time
Create/send/receive reports	Often
Create/send/receive free text messages	Occasionally
Check location of friendly units (from other units/allies)	Occasionally
Check location of other areas of interest	Occasionally

In general, M&DC2 Soldiers rated most functions easier to learn than ABCS Soldiers, and easier to perform as well. A few functions were rated more difficult to learn and employ, but for the majority of functions, M&DC2 Soldiers thought they were easier to learn and also easier to employ.

It is tempting to conclude that future force systems will be easier to train and easer to employ than current systems. However, comparisons of difficulty learning the functions and difficulty performing the functions for the two groups should be eyed with caution. The difficulty Soldiers experience learning about C3 functions and employing them stems not from a single source but is a combination of a number of factors. The intrinsic difficulty in performing a function is influenced by the quality and quantity of training the operator receives, and the quality of design of the Soldier-system interface. Therefore, whether some functions are inherently easier or more difficult than others cannot be determined, particularly across different systems.

On the other hand, since M&DC2 Soldiers rated many functions easier to learn and perform than ABCS Soldiers, then clearly some variable in the M&DC2 Soldier's experience influenced their rating. There are several possible reasons for this, including some difference in the groups of Soldiers, differences in training, and differences in the systems interface.

The first possibility is there may be some difference between the groups of Soldiers regarding military experience or computer experience. However, the demographic data show each group has roughly the same military experience, measured by years of service (ABCS Soldiers averaged 4.8 years of service, M&DC2 Soldiers averaged 4.2 years). The groups also had similar levels of computer experience. Although fewer M&DC2 Soldiers reported owning PCs (71%, versus 91% of ABCS Soldiers), when this difference was analyzed using a Chi-square, the difference was found not to be significant ($\chi^2 = 1.6$, $df = 1$, *n.s.*). Also, both groups of Soldiers had about the same level of familiarity with office-type software, since all ABCS Soldiers said they were familiar with this type software, and all but one of the M&DC2 Soldiers were familiar with office software. Therefore, there does not seem to be a difference between these groups of Soldiers relating to military or computer experience.

On the other hand, ABCS and M&DC2 Soldiers had different levels of training. All M&DC2 Soldiers completed a formal training program to operate the simulated C3 system, whereas slightly more than half of the ABCS Soldiers reported attending formal training for ABCS systems.

The third possibility is related to the systems interface. The M&DC2 displays and controls were designed to work together, whereas ABCS systems, although they

can share information, were originally designed to operate independently in a "stove pipe" fashion. The greater attention to interoperability may have led to better Soldier acceptance.

However, since both the training and the interface differed between ABCS and M&DC2, it is impossible to determine what made M&DC2 easier for Soldiers to learn and employ. Future research in this direction could answer this question.

Finally, it is interesting to note that M&DC2 participants employed free text messages as often as ABCS soldiers. Many ABCS systems use pre-formatted messages for specific purposes, and presumably, these pre-formatted messages are easier to use than creating free-text messages because only minimal information is required to be input in the message before it is sent. However, free-text messages are employed by both ABCS and M&DC2 Soldiers, which suggests that there are and will continue to be situations where free-text messages are useful to Soldiers.

Concerns Over Small Sample Size

There is a valid question about the applicability of the research results considering the relatively small size of the sample. A major drawback of field research is that the researcher often has little control over certain aspects of the research, such as how many participants are available to complete the research. A small sample size is not, in itself, a problem, but how it affects statistical inference may be. For this reason it's important to understand the consequences of a small sample, and how it affects the generalizabilty and validity of the results.

One affect of a small sample size is that it can reduce the statistical power of the test and lead the researcher to an inappropriate conclusion, such as concluding that there is a difference between the groups when in fact no difference exists, or vice versa. In the case of the present research, the Chi-square analyses sought differences between the groups of Soldiers. As a non-parametric test, Chi-square is more robust to small samples than a parametric statistic, providing the requirements for minimum cell frequencies are met, as they were in the present research. To be valid, the Chi-square would require sufficient power to identify differences between groups at an acceptable level of significance (α level). Generally, an acceptable α level would be $p < .05$ or less. In the present research, the Chi-square analyses which identified differences between groups did so at levels of significance (α levels) of $p < .001$. Thus, regardless of the sample size, the analyses had sufficient power to allow the researcher to make a valid inference. For a more in-depth discussion of statistical power, see Siegel and Castellan (1988).

Another problem of a small *N* is that extreme scores can skew the means enough that the mean scores do not correctly represent the majority. One dissenting opinion in a small group can markedly bias the average scores. For this reason, modes were used in the data analysis where possible. Because the mode is the score that occurs most often, it more accurately represents the opinions of the majority of participants.

A final concern is that research based on a small sample may not be generalizable to the population at large. By chance, the sample may contain an unusual number of individuals who differ from the population at large in some way and therefore do not adequately represent the population, a problem similar to the extreme scores, above. The fact that the Soldiers in this research come from diverse backgrounds tends to reduce this possibility, however, the reader should carefully weigh these considerations when applying the results of this research.

Implications for Future C3 Design

The fact that future force Soldiers preferred to use digital tools more often than ABCS Soldiers suggests that the M&DC2 concept is moving in the right direction. Soldiers tend to be practical and will often not use tools which have marginal utility and/or are difficult to employ. Since M&DC2 Soldiers preferred using digital tools and functions more often than ABCS Soldiers, presumably M&DC2 Soldiers found them more useful.

There are a number of ways the present research can be applied. Engineers who design networked C3 systems for future forces can use these results to get an idea of which digital C3 functions Soldiers may use most often and focus design efforts on those functions. For example, we know that some C3 functions are useful only in certain situations, whereas others are employed frequently and are applicable to most situations. Future designers would want to ensure they focus on the widely applicable functions that are used most frequently. The research suggests that such functions include those that (1) involve visualizing the battlespace, particularly the blue or friendly situation, (2) involve sharing data, including orders, reports and graphics, and (3) planning missions and developing planning products. Future designs should also include the ability to send and receive unstructured messages, such as free text messages, since it is likely Soldiers will continue to find unstructured messages useful.

Future designs should also include a Soldier-centered design philosophy in the design of the interface. Such a design philosophy tends to reduce unnecessary task complexity and make functions more straightforward to employ, thus increasing the probability Soldiers will employ the functions, since previous research indicates Soldiers tend not to employ tools which are difficult to use (Barnett, 2005).

Finally, trainers can use this information to plan training programs for future commanders and staff officers. The present research reinforces the concept that training which is well-integrated into the fielding process improves the usability and functionality of the system, and increases the probability that Soldiers will properly employ the systems. A well timed and well integrated training program can have a positive affect on system usability.

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