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Recommendations for Collective Training for the Battle Management System

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ABSTRACT

This report documents the results of a literature review in collective training for Battle Management Systems. Articles reviewed include experiments, interviews with experts, reports from implementation of Battle Management Systems, and psychological literature on learning and training. Recommendations for a collective training product are provided.

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Recommendations for Collective Training for the Battle Management System

Executive Summary

The Australian Army is current acquiring a dismounted Battle Management System (BMS) as part of Project Land 75. This report investigates the use of BMSs by overseas military, and provides recommendations for the acquisition of a collective training capability for use in Australia.

Based on a literature review of experimental studies, interviews with Subject Matter Experts, reports on military collective training, and psychological research in learning and training, a BMS collective training package should:

- facilitate understanding of weaknesses in the system and basic workarounds;
- follow a crawl-walk-run approach;
- be easily broken down into component tasks;
- provide appropriate feedback from the BMS;
- allow the instructor ample opportunity to view the learners' performance;
- take into account military personnel's existing knowledge and skill levels;
- provide opportunities for hands-on experience or active participation;
- provide sessions for ongoing maintenance of skill and knowledge; compensate for missing team members, and provide simulation of other echelons in a Combined Arms Team environment;
- resemble live environment, including suboptimal working conditions,
- enhance user SA of battlefield; and
- cater for limitations in human information processing capabilities, to not overload operators and trainers.

The successful application of the principles noted above will form the basis of a successful collective training capability for BMSs for the Australian Army.

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Glossary

AAR	After Action Review
BMS	Battle Management System
C2	Command and Control
DMO	Defence Materiel Organisation
IAD	Immediate Action Drill
OPFOR	Opposing Force
SA	Situation Awareness
SME	Subject Matter Expert
TDX	Tactical Decision making Exercises
TRADOC	Training and Development Command

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1. Introduction

Armies around the world are adopting sophisticated command and control (C2) systems. These systems, generically referred to as Battle Management Systems (BMSs), provide information about the status of individuals, units, and equipment, such as Blue Force Tracking capabilities, electronic messaging, and networked communication. In recent years, BMSs have been trialled or adopted by the armed forces of the USA (Dunivan, 2003), the UK (National Audit Office, 2006), Germany (Anonymous, 2001), and Sweden (Wikberg, et al. 2003).

The Australian Army is currently acquiring a dismounted BMS as part of Project Land 75[1]. One work package within Project Land 75 is the acquisition of a collective training support package for use in Australia. This report is written to support this work package.

The aim of the report is to provide recommendations for content to be included in the collective training package. Recommendations are derived from two sources,

1. A detailed review of training issues associated with the implementation and use of BMSs by military forces worldwide, including:
    a. Experimental studies in areas such as skill acquisition and decay,
    b. Interviews with Subject Matter Experts (SMEs), such as commanders and soldiers with experience in using BMSs,
    c. Reports on the implementation of one particular BMS, known as Bowman, in the British Army,
    d. Literature reviews and bibliographies on military collective training, and
2. A brief review of relevant psychological principles relating to training and skill acquisition.

It is outside the scope of this report to include an exhaustive discussion of all psychological principles relevant to skill acquisition and training in BMSs[2]. Rather, selected studies or theories have been cited in support of training issues identified from the implementation of BMSs worldwide.

In addition, as there is a limited amount of unclassified published information on the implementation of BMSs in foreign military forces, some anecdotal or subjective evidence on BMS implementation has been included, as has evidence from other complex environments, such as aviation. Where this limits the extent to which conclusions can be drawn from these data, this is discussed in the body of the report.

The structure of the report is as follows. Section 2 provides a brief overview of BMSs generically, and Australia's requirements under Project Land 75. Section 3 summarises the key findings from the reviewed literature, including deficiencies in existing BMS training

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[1] While the BMS acquisition under Project Land 75 was combined with the acquisition of a mounted BMS under Project Land 125 (e.g. Muir, 2008), the focus in this report is on BMSs used by dismounted forces.

[2] For more detailed review and discussion of these issues see Goodwin (2006).

and use; characteristics of skill acquisition and maintenance; suggestions for developing shared understanding; and advantages of contextual training. Recommendations for a BMS collective training package are contained in Section 4.

This work was conducted under Task 07/024 in DSTO's Land Operations Division, in support of Project Land 75.

2. Overview of the BMS

BMSs are intended to improve the effectiveness of military operations and decision-making, through the provision of accurate and timely information. This requires the synthesis of a wide variety of information relating to the location of individuals, units, and assets. BMSs typically comprise a variety of digital equipment, including radios, maps, and messaging systems (Grynovicki & Kysor, 2003).

Under Project Land 75, the initial Australian tender requirements for a BMS were for a Battle Group and Below Command, Control and Communications system. This was to include a combat radio system, a network management system, and a support system to integrate them (DMO, 2008). Subsequently, the tender requirements for Project Land 75 were later combined with Project Land 125, which sought to provide a mounted BMS (Muir, 2008).

In March 2010, it was announced that Elbit Systems was the successful tenderer for Project Land 75/125. An example of the Elbit BMS is shown in Figure 1.

Figure 1: An example of the Elbit BMS (source: http://62.0.44.103/elbitmain/area-in2.asp?parent=4&num=41&num2=41)

3. Review of training issues associated with the BMS

A literature review was conducted, examining the implementation of BMSs worldwide. Articles reviewed included experimental studies undertaken as part of implementation programs, published interviews with soldiers and commanders experienced in the use of BMSs, specific case study reports on the British Bowman program, literature reviews on military collective training, and psychological literature on training and skill acquisition.

Findings from the review are summarised as follows. Section 3.1 discusses issues associated with the acquisition, maintenance, and decay of skills required to operate BMSs, referred to generically as "digital skills". Section 3.2 discusses the collective training requirements for developing shared understanding in users of a BMS. Section 3.3 discusses the importance of contextual training, or "training as you fight". Section 3.4 examines issues relating to workload during BMS training and operational use, and Section 3.3.1 discusses the requirement to train users to accommodate deficiencies in digital systems.

3.1 Skill acquisition

3.1.1 Instructor preferences

BMSs are more generally complex than the analogue systems they are replacing. Consequently, they have increased training requirements (e.g. Ferrell, 2002; Goodwin, 2006). This section examines the development of skills in the use of a BMS, focussing on the preferences of trainers or instructors, with trainees' preferred modes of learning covered in the next section.

In psychological models of skill acquisition (e.g. Anderson, 1983; cited in Anderson, 1995), there are three broad stages to acquiring a skill. In the first stage, the cognitive stage, learners acquire the 'rules' of the skill through rote rehearsal. At this stage, most elements of performance are broken down into very small components. In the second stage, the associative stage, learners begin to associate the facts that they have learned, bringing together the components of the skill or task. In the third stage, the autonomous stage, learners are able to perform the skill fluently, with a higher degree of automaticity.

The US Army adopts a similar approach to skill acquisition, the "crawl-walk-run" approach. (e.g. Department of the Army, 2002; Sanders, 2002; Schaab & Moses, 2001; Zipperer, Klein, Fitzgerald, Kinnison, & Graham, 2003). During the 'crawl' phase, the emphasis is on learning the individual components of the skill or task. During the 'walk' phase, the components are integrated, at a slower than normal pace. Finally, during the 'run' phase, the skill or task is performed at normal speed, with conditions similar to actual combat conditions. This approach forms the basis of the U.S. Army's Training and Doctrine Command program (TRADOC, 2004), and is strongly supported by current and former U.S Army personnel (e.g. Zipperer et al., 2003). TRADOC (2002) suggests that the crawl-walk-run approach should apply to the progression from individual to collective training, that is, military personnel should have a good understanding of individual roles and responsibilities before working in a group. Similar approaches to training have been suggested by other authors (e.g. Deatz & Campbell, 2001; Johnston, Leibrecht, Holder, Coffey, & Quinkert, 2002; Salter & Black, 1998; Throne & Burnside, 2003; Wampler, Dyer, Livingston, Blackenbeckler, Centric, & Dlubac, 2006)

In practice, military training programs do not rigidly adhere to the three steps either in the cognitive-associative-autonomous (Anderson, 1995) or crawl-walk-run (Department of the Army, 2002) approaches. For instance, Leibrecht, Johnston, Black and Quinkert (2002) note that due to operational constraints, while the crawl-walk-run stages may be used, the three stages may occur concurrently or out of sequence. Other authors suggest that there should be a combination of theory and practice at all stages. For instance, Deatz, Greene, Holden, Throne, and Lickteig (2000) suggested that training should be a five stage process:

1. orientation to organisation and processes;
2. fundamental skills;
3. functional skills;
4. individual and collective tasks; and
5. TDXs (Tactical Decision making eXercises) on staff processes and cognitive skills.

Similarly, Schaab and Moses (2001) suggest that training should comprise a series of vignettes, each with a crawl-walk-run progression. Their conception of current and recommended method of training is shown in Figure 2. Schaab et al. (2004) suggested there should also be a crawl-walk-run progression from watching the BMS demonstrated to hand-on experience with the BMS.

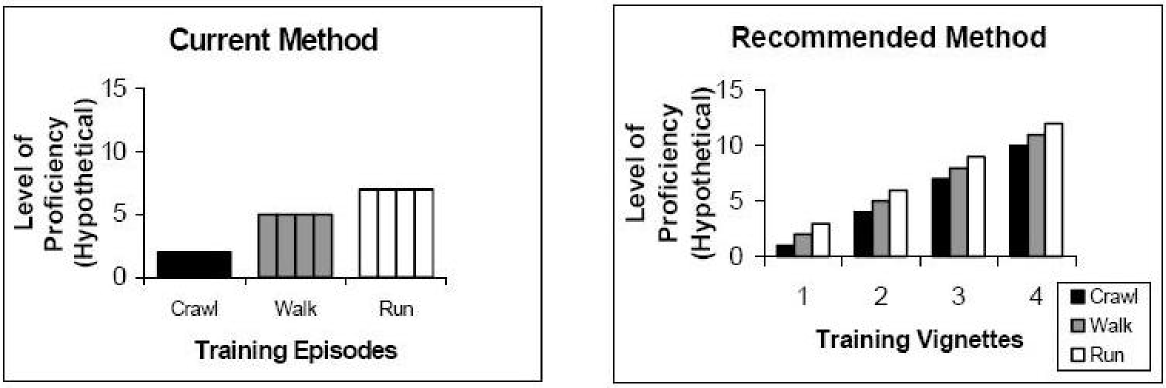

Figure 2. Current and recommended methods of "crawl, walk run" training

(From Schaab & Moses, 2001, p12)

3.1.2 Trainee preferences

In addition to considering instructors' preferences, researchers have also examined trainees' preferred learning style. Deatz and Campbell (2001) recommend that training should involve a variety of different learning methods, such as watching the tasks performed, performing each of the components of the task in sequence, and practising the task.

Despite the recommendation that training involve a variety of different teaching methods, military personnel seem to prefer hands-on learning above all other styles (e.g. Deatz et al.

2000; Ferrell, 2002; Schaab & Dressel, 2003; Schaab et al., 2005). For instance, Deatz et al. conducted a study testing four different training approaches. These approaches were: a demonstration of the BMS, drills rehearsing specific functions within the system, small scale mock exercises, and larger scale mock exercises. Each training approach was used to develop a training product, which was tested by a group of military personnel. They rated each training product for factors such as the perceived benefit of the training product, and the extent to which the training product taught them to use the BMS. Results showed that the mock exercises were rated as the most beneficial training products, and the demonstration rated as least beneficial. While these data are self-reported, and not corroborated with objective measures, they are in line with the recommendations given by Goodwin (2006) in his literature review on the training, retention and assessment of digital skills. They are also in line with Wampler et al.'s (2006) review of the training studies they had conducted.

The general preference in military personnel for hands-on – also known as constructivist - learning is supported by some experimental evidence. In a study conducted by Schaab and Dressel (2001), military personnel taking part in an 83-day introductory military course on BMSs were divided into two groups on Day 66. One group received a series of conventional lectures describing how to use a BMS, while a second group completed a series of practical, hands-on exercises. These exercises built on the trainees' existing knowledge of the BMS, and of C2, and encouraged the students to think about the broad principles underlying the system. This training took approximately seven days.

Following this training, both groups were given an examination testing material and situations similar to the coursework material, and an exam testing unfamiliar situations. Schaab and Dressel (2001) report that results on the first examination did not differ between groups. However, on the examination testing unfamiliar situations, the conventional training group performed significantly worse than the group given hands-on training. These results appear to suggest that conventional and hands-on training are equally effective in training for familiar situations, but hands-on training is more effective in training for novel situations.

The preference for hands-on learning does not mean that all styles of hands-on learning are equally effective. Some guidance or structure to hands on learning is necessary to ensure learning effectiveness. This is demonstrated in an experiment conducted by Dyer and Salter (2001), where military personnel given formal instructions on using a digitised map system performed significantly better than military personnel who were given no formal instruction, but were instead given time to explore the map functions, with no formal guidance or feedback. These results were replicated in a later study by Dyer, Singh, and Clark (2005).

Apart from the studies conducted by Schaab and Dressel (2001) and Dyer and Salter (2001), there is little formal evaluation of the impact of different training methodologies on BMS training outcomes. In addition, as noted by Goodwin (2006), the majority of available evidence only examined the impact of training styles on retention for periods up to one month, and there is little evidence on the retention of skills beyond this timeframe. However, given the available evidence, it is recommended that BMS training use a constructivist learning approach. This should incorporate hands-on exercises, with guidance and direction.

3.1.3 Existing skill and knowledge levels

In addition to trainee and trainer preferences, it is important that BMS training takes into account trainees' existing skill and knowledge levels. Evidence from the implementation of Bowman suggests that the amount of training required should not be underestimated. The House of Commons report (2007) and the National Audit Office report (2006) both suggested that a system as complex as Bowman requires continuous training, especially as additions to the system were implemented after the core system had been introduced into service. The reports indicated that digital training costs are considerably higher than training costs for an analogue system, due to the increased complexity of the system.

There are a variety of categories of existing knowledge and skill that should be taken into account. First is basic literacy. Evidence given to the U.K Select Committee on Public Accounts (House of Commons, 2007) suggests that training on the Bowman system was hampered by low literacy levels within the British Army. One member of the Committee suggested[3] some military personnel had reading ages as low as 11 years, which resulted in considerable difficulties reading the Bowman instructional manual. While this has not been independently verified, if true, it would have considerable implications for training.

In addition, existing computer skill levels need to be taken into account. As noted by Campbell et al. (1998), while there is a common perception that younger military recruits have high levels of computer literacy than their older counterparts, this is not supported by evidence. Similar results were reported by Dyer (2009) and Tucker et al. (2009). In addition, Dyer, Centric and Dlubac (2006) note that there is a difference between basic computer literacy, and the kinds of computer skills required to use a complex BMS.

Finally, trainees' existing military skill levels and knowledge requirements need to be taken into account. This includes knowledge of military acronyms and tactics (Tucker et al., 2009), and knowledge of military procedures, such as making combat orders (Dyer et al., 2006; Dyer & Tucker, 2009).

3.1.4 Feedback

Whatever learning style or styles are adopted, feedback is essential for improving performance. This is reported in both the psychological literature (e.g. Cronbach, 1963; cited in Wampler, et al., 2006), and reports of implementation of BMSs in military forces (e.g. Deatz et al., 2000; Throne & Burnside, 2003; Zipperer et al., 2003). Wampler et al. (2006) suggested that feedback should be provided in two ways in BMS training; through the BMS, and through the training. Wampler et al. suggest that the BMS should provide feedback, including appropriate auditory and visual responses, such as displays of trajectories. This is known as augmented feedback. There is experimental evidence to suggest that augmented feedback can help in the acquisition of complex military skills

[3] See Q39 in the oral evidence.

(e.g. Lintern, Thomley, Nelson, & Roscoe, 1984) as well as simple motor skills (e.g. Anderson, Sekiya, Magill, & Ryan, 2005; Kinkade, 1963). There is experimental evidence that augmented feedback is effective in a virtual environment as well as in a live environment (Todorov, Shadmehr, & Bizzi, 1997).

However, augmented feedback does not universally result in improved performance, as demonstrated in several of Lintern's studies. In Lintern and Koonce (1992), augmented feedback improved performance only for conditions with low visual detail, and in Lintern and Roscoe (1978; cited in Boldovici, 1992), augmented feedback proved detrimental to performance. Lintern and Koonce suggest that augmentation is effective only where it does not allow trainees to become dependent on the augmenting information.

In addition to providing augmented feedback during training, feedback should be provided by the trainer. This may be as part of a formal After Action Review (AAR), or as less structured advice and commentary throughout training. Wampler et al. (2006) highlight that the trainer should be able to observe the trainee during important tasks, and that this capability usually needs to be incorporated into the system design, as it is often too expensive to modify the system after purchase. Hence, it is recommended that the BMS training product should be capable of providing augmented feedback during training, and facilitating an AAR after training. This should include the ability to record and replay training sessions.

3.1.5 Skill maintenance and decay

Once skills have been acquired, some maintenance is required, or they will decay. However, there is some contention over the extent to which digital skills, such as those required to use a BMS, decay through lack of use, or lack of practice. There is a strongly-held belief among military personnel that these skills are highly perishable (e.g. Dudley et al., 2001; Ferrell, 2002; Johnson et al., 2002; Salter & Black, 1998), and hence, that they need constant practice. However, close examination of these papers shows that most are based on the opinions of Lynch (2001) and Elliot, Sanders, and Quinkert (1996). Lynch was a Commanding Officer in the U.S Army's 4th Infantry Division, the U.S Army's first digitised Division. He states emphatically that digital skills are extremely perishable, but provides no supporting evidence. Elliot et al. (1996) tracked a unit through eight months of training on several BMSs. Questionnaires administered to the participants showed a strong belief – but no other evidence – that digital skills were perishable.

More objective evidence on the decay of digital skills is provided by Schaab and Moses (2001), who tracked the progress of a group of military personnel for almost a year, as they progressed through advanced training. They discovered that both the assumptions of rapid decay and a need for constant practice appeared inaccurate. The military personnel's digital skills were largely intact three to four months after initial training, with military personnel practising an average of only two hours per week.

This suggests that digital skills may be far more enduring than has been suggested previously. It may be the decay of digital skills is dependent on a number of other factors, related to skill type, degree of learning, and practice conditions. Indeed, there is evidence from the psychological literature (e.g. Arthur, Bennett, Stanush, & McNelly, 1998) that cognitive skills, such as problem solving and decision making, decay more quickly than physical skills, such as coordination. Furthermore, skill decay is far less likely if the skills were initially learned beyond proficiency (Arthur et al., 1998). In addition, retention is greater if learning is distributed rather than massed, i.e., spread out over time, rather than concentrated in a short timeframe (e.g. Rohrer & Taylor, 2006). Therefore, a broad recommendation is that any collective training program should include scope for ongoing training.

One caveat on this recommendation is that, as discussed in Section 3.1.2, Goodwin (2006) noted that most studies on the acquisition and degradation of digital skills examined the retention of skills for short periods of time, less than a month. He suggested that more research was required to assess degradation of digital skills over longer time periods.

3.2 Developing shared understanding

As noted by the Department of the U.S Army (1999; cited in Burnside & Throne, 2004), collective training should encompass both individual and group training. SMEs and Army personnel suggest that this has two dimensions. Firstly, any BMS training program should be robust enough to cope with missing unit members, or situations where learners transfer in or out of units (Johnson et al., 2002). Secondly, a BMS training program should cater for the different roles and levels of knowledge held by individuals and units. Schaab et al. (2005) suggests this should also extend to training military personnel in the use and understanding of BMSs other than the system they most commonly use.

Dudley et al. (2002) examined the impact of digitisation on different echelons within the U.S Army. They compared the level of information required from a BMS at Battalion and Brigade level. They concluded that at Brigade level, military personnel needed greater familiarity with the BMS, and greater knowledge of its capabilities, due to the higher volume of information they deal with. For example, there is a higher degree of coordination required at Brigade level than at Battalion level. The BMS and staff at Brigade level need to be able to cope with this increased workload and information. Although Dudley et al. (2002) do not explicitly state this, it suggests that training materials be targeted for specific units, rather than adopting a one size fits all approach. This is supported by Leibrecht et al. (2002, 2004), who suggest that training should be tailored for specific individuals, not just specific units.

Collective training was poorly implemented in the deployment of the Bowman system. The National Audit Office report (2006) notes that there was no provision for commanders and staff to be trained on higher-level use of the BMS. Moreover, military personnel were trained individually, at a central location away from their home units. They were not trained alongside the military personnel they would be working with. This resulted in generic training, which lacked training on elements specific to each service, e.g. Infantry or Artillery. Based on these reports, it is recommended that a BMS training program be highly customisable.

3.2.1 Situation awareness and shared mental models

It is generally accepted that good situation awareness is required for teams to function effectively, including military teams. SA is an understanding of elements within the environment, including understanding of current states, and projection of future states (Endsley, 1995)[4]. This may include, for instance, seeing three tanks on a BMS screen, recognising that they are part of a platoon, and understanding their likely movement pattern (Schaab & Dressel, 2003).

Researchers (e.g. Deatz & Campbell, 2001; Schaab & Moses, 2001) have identified the importance of a training system facilitating the development of individual soldiers' SA. For instance, Deatz and Campbell noted that was important for the training system to support the development of SA. They also suggested that instruction should be structured such that new information or knowledge builds onto existing knowledge of the functions and structure of the BMS. They suggest that this facilitates development of SA, as military personnel are able to develop increasingly detailed mental models of the BMS. Similarly, Schaab and Moses (2001) noted that an essential part of digital skills training is facilitating the development of users' shared SA. They give an example of military personnel's development of SA, progressing from remembering the meaning of symbols on a BMS display, to using this to create a mental picture of the Area of Operations (AO), to using this information to construct battle plans.

Another factor that may contribute to SA and shared understanding is mental models. For instance, based on their SME interviews and literature review, Dudley et al. (2001) note that it is important for each member of a team to understand the roles and responsibilities of other team members. Military personnel surveyed in their study reported that they needed to know what information their commander would find useful, e.g. 'I would like to know what the Battle Captain needs, instead of him having to tell me'. Other surveys of military personnel's views (e.g. Johnson et al., 2002; Schaab et al., 2005) and a review of literature and existing military training (Wampler et al., 2006) also support the finding that understanding of team members' roles and responsibilities is important. Similarly, Schaab et al. (2004) suggest military personnel be trained to understand the BMS's capabilities, rather than simply memorising by rote its functions, and commands. They suggest this provides military personnel with greater understanding of the system, and greater skill and flexibility in use of the BMS, resulting in considerably enhanced SA. Based on these reports, it is recommended that any BMS training program place considerable emphasis on using the BMS to develop and enhance the user's SA.

3.3 Contextual training

It is important for training to be conducted in the right context if it is to be effective. Thorndike (1906; cited in Anderson, 1995) proposed that the degree to which skills learned in training transfer to other environments can be explained under a theory of identical

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[4] It is acknowledged that SA is a complex concept. It is beyond the scope of this report to address all the complexities, but more detailed discussions are contained in Stanton et al. (2006) and Salmon, Stanton, Walker, and Green (2006).

elements. According to this theory, skills learned in training will transfer to similar activities, but not dissimilar activities. Similar principles apply to the transfer of knowledge. For instance, studies (e.g. Godden & Baddeley, 1975; Murnane & Phelps, 1993) have shown that retention of learned material is better when training and test environments are similar or identical. Transfer of training is also enhanced when mood is similar at study and test, for instance, material learned in a stressful environment is best recalled in a stressful environment (Bower, Monteiro, & Gilligan, 1978; cited in Anderson, 1995).

More recent research (e.g. Lintern, 1995) has suggested that it is not necessary for training and test environments to be identical, and that effective training can occur when they are dissimilar. Lintern described several previous studies where transfer of flight skills was more effective when there was dissimilarity between the training environment and the test environment, such as the presence or absence of cross-winds. His view was that it is important to focus on essential or critical similarities, while disregarding non-essential or irrelevant similarities.

The concept of a training environment similar to the test environment is known within the military as "training as you fight", where emphasis is placed on the training environment replicating as many aspects as possible of the combat or operational environment. This approach includes using the same equipment in training and live environments (Throne & Burnside, 2003; Tucker et al., 2009; Wampler et al., 2006), replicating typical operating conditions (Deatz & Campbell, 2003; Lickteig, Sanders, Durlach, & Carnahan, 2004; Schaab, Dressel, & Moses, 2004), working with other echelons (Lickteig et al., 2004; Schaab et al., 2004), and training military personnel to cope with 'surprises' or non-routine events, such as equipment failure or unexpected encounter with the opposing force (OPFOR) (Zipperer et al., 2003).

Ideally, training material should also be adaptable, in order to meet specific requirements. These requirements may include specific environmental requirements, missing team members, and malfunctioning equipment (Burnside & Throne, 2004; Throne & Burnside, 2003; Wampler et al., 2006). Training must be able to change to accommodate units' growing knowledge, e.g. Johnson et al. (2002) ask, why stick with an arbitrary 0600 crossing of the Line of Departure, if the troops have the knowledge and information to allow them to go earlier?

Caveats to the use of training as you fight have been raised by several authors, including Lintern (1995) and Schneider (1985). As previously noted, Lintern (1995) demonstrated that elements of dissimilarity could produce effective training. In addition, as discussed in some detail by Schneider (1985), the assumption that 'training in the real world' is the best form of training may be flawed, and that similarity between training and test may not be required. While it is beyond the scope of this report to discuss these caveats in detail, it is noted that neither Lintern nor Schneider recommended disregarding similarity. Rather, their argument was that similarity should be used where it was essential for effective training, and disregarded where it was non-essential or counterproductive. Given the limited research that has been conducted on BMS training, it is not possible to identify which elements of the operating environment are "essential" or "non-essential" for training.

Based on the evidence reviewed in this section, it is recommended that the BMS training program should be highly customisable. The program, and the BMS, should replicate the operational environment in which the BMS will be used. The scope of this recommendation should be re-evaluated and refined if evidence becomes available to indicate that certain elements of the operating environment are not required to be replicated in the training environment in order to produce successful learning (i.e., are what Lintern (1995) considered non-essential or irrelevant).

3.3.1 Deficiencies in digital systems

One aspect of "train as you fight" that is worthy of greater elaboration is an acknowledgement of the deficiencies in digital systems. When they were first introduced into the US Army, personnel were critical of deficiencies in the systems. As reported by Schaab, Dressel, and Moses (2004), these deficiencies included the time taken to boot up computer systems, interoperability with other systems and the frequency of computer malfunction. These deficiencies had a substantial impact on operations, as they increased the time taken to transmit information (often taking longer than it would manually) and resulted in loss of information processing and communication capabilities (Schaab, Dressel, & Hayes, 2005; Schaab & Moses, 2001). Dudley, Johnson, Jones, Strauss and Meliza (2001) reported that one common criticism from military personnel was that their troubleshooting capacities were limited, e.g. while a problem may only have taken moments to fix, it may have taken an hour to find the one person in the Brigade who knew how to fix it.

More complex deficiencies with digital systems were reported in the UK Bowman project, which replaced the British Army's aging analogue radio handsets with newer digital handsets. The drivers for the replacement of the radio handsets were increased communication security, increased information transmission, and a move towards digitisation (National Audit Office, 2006). However, when the radio handsets were introduced into service, a number of deficiencies became apparent. For instance, Smith (2004) reported that the handsets gave soldiers radiation burns if they were used at their highest setting. This problem was 'solved' by turning down the radio settings, which reduced their transmission capabilities. Other problems included the fact that the radios were three times heavier than the obsolete radios they replaced (National Audit Office, 2006; Smith, 2004), and that the lifespan of the batteries was considerably less than the batteries used in the predecessors (Smith, 2005). Moreover, the radios were tied to a specific callsign, and were part of a complex system of electronic webbing, worn by the soldier. As a consequence, if a soldier became immobilised or incapacitated, it was virtually impossible for his colleague to pick up his radio and use it; since it would require re-keying, and also removal of the first soldier's webbing.

Researchers have proposed several suggestions for training military personnel to deal with deficiencies in digitised systems. For instance, Schaab and Moses (2001) suggested that military personnel be taught about known problems with BMSs, and given training in working around them. They suggested this should include teaching military personnel immediate action drills (IADs) to fix a malfunctioning system, just as they are taught IADs to fix a jammed weapon.

In addition, Campbell, Ford, Shaler and Cobb (1998) suggest that it is important to continue to teach soldiers how to perform tasks manually, or without digital equipment, e.g. navigating by compass and map rather than by satellite. While this will provide soldiers with the ability to carry out their work in the case of system breakdowns, the requirement to teach soldiers to perform tasks manually as well as digitally may increase the cost and time of training.

There is some experimental evidence that addressing BMS deficiencies in training can improve military personnel's attitude towards the BMS. For instance, Barnett (2004) examined changes in attitudes towards BMSs before and after training. He found that, after training, military personnel reported a better understanding of the deficiencies in the BMS. For instance, post-training there was a substantial increase in the number of participants disagreeing with the statement "I know that the information I get from [the BMS] is accurate", and a substantial increase in the number of participants who agreed with the statement "Sometimes there are easier ways to do things in [the BMS] than what's shown in the book". In addition, training significantly increased the soldiers' ratings of the BMS's ability to enhance communication and situation awareness. This suggests that training programs that cover deficiencies of a BMS can improve soldier attitudes towards the systems.

3.4 Workload

3.4.1 Workload in training

Psychological experiments have consistently demonstrated that humans have limited information processing capacities and that to exceed these capacities results in decreased performance. For instance, Miller (1956) demonstrated that humans can maintain only about five to nine items in working memory. Working memory capacity can be increased by chunking, that is, by combining individual pieces of information into larger units, or 'chunks'. However, the rule of thumb of seven plus or minus two generally still applies. There is also evidence (e.g. , 1908) there is an optimal level of arousal under which performance is maximised. Performance is represented as an inverted U-curve; it increases until the optimal level of arousal is reached, and decreases afterwards.

Researchers have considered the application of these principles to BMS training. For instance, Deatz and Campbell (2001) suggested that more information would be retained if it was grouped into 'chunks', each chunk dealing with a separate stage of operation, e.g. starting the BMS, performing a specific task, and shutting down the BMS. In addition, Dyer and Salter (2001) found that reducing the amount of information trainees had to memorise, through use of chunking, tended to improve retention.

As noted by Meliza, Lockaby, Perault, and Leibrecht (2004), it is not just the trainees' workload that needs to be considered, but also that of the trainers. They note that trainers can be ‘overwhelmed’ by the demands of managing collective training, and suggest that that digitisation has made it more, rather than less, likely, that trainers will be overwhelmed. They cite research (Brown, Nordyke, Gerlock, Begley, & Meliza, 1997; cited in Meliza et al., 2004) suggesting that digitisation causes a substantial increase in the trainers’ workload.

Based on this, Meliza et al. (2004) developed a manual for trainers conducting digitised collective training, the Digital Tactical Operations Center Integration Guide. It contains a number of recommendations for successful trainers and training, for instance:

- Material should be quick and easy to prepare, and easily accessible to all users.
- Training and training material should be structured so that critical information is easily noticed.

No other material has been found on the implications of the digitised battlefield for trainers’ workload. However, this is an area worthy of further investigation.

3.4.2 Workload in the operational environment

Meliza et al. (2004, p4) commented that one of the benefits of digitisation is that “planning never stops for the digitized unit… because plans can be changed to take advantage of new information.” Although Meliza et al. consider this an advantage, it is also a potential disadvantage. As noted by Goodwin (2006), it is possible that this continuous flow of information may exceed information processing capacity. If this occurs, psychological theories (e.g. Broadbent, 1958; Treisman, 1960; cited in Haberlandt, 1997) suggest that some information may be ignored. Prevou (1995) suggests that this should be dealt with by using a ‘push/pull’ approach, where routine information is stored in the system and needs to be *pulled* by commanders and subordinates when required, but critical information is *pushed* at the commanders, so they are made immediately aware of it, and less likely to ignore it.

Another implication of using digitised battle systems in the live environment is noted by Dunivan (2003). He comments that many great military leaders have given short orders, and allowed their subordinates to execute them as they saw fit. However, with BMSs, there is a risk of micromanagement. That is, when higher echelon commanders are able to see all aspects of the battlefield, and all echelons, they may reduce the initiative devolved to subordinates, and exercise a greater than necessary degree of control over lower echelons (e.g. Dudley et al., 2001; Ferrell, 2002; Fox, 1995). It may be possible to address these issues in training. Similarly, Dudley et al. (2001) acknowledge the need to train leaders to understand the cost of information, and to understand what they are seeing on the screen. As discussed in Section 3.2.1, it may be useful if subordinates also have some understanding of their commander’s requirements.

4. Recommendations for a BMS collective training system

Based on the literature reviewed in the preceding sections, it is recommended that a BMS collective training system should:

- Follow a crawl-walk-run approach (Section 3.1).
- Be easily broken down into component tasks (Section 3.1).
- Facilitate a constructivist learning approach, incorporating hands-on experience or active participation (Sections 3.1.2 and 3.3).
- Take into account military personnel's existing knowledge and skill levels (Section 3.1.3)
- Provide appropriate feedback from the BMS (Section 3.1.4).
- Allow the instructor ample opportunity to view the learners' performance (Section 3.1.4).
- Provide sessions for ongoing maintenance of skill and knowledge (Section 3.1.5).
- Compensate for missing team members, and provide simulation of other echelons in a Combined Arms Team environment (Section 3.2).
- Enhance user SA of battlefield (Section 3.2.1).
- Resemble live environment, including suboptimal working conditions (Sections 3.3 and 3.3.1).
- Facilitate understanding of weaknesses in the system and basic workarounds (Section 3.3.1).
- Cater for limitations in human information processing capabilities, to not overload operators and trainers (Section 3.4).

With armies around the world increasing their adoption of digital C2 systems, collective training is integral to the successful rollout and implementation of such systems. By adopting the recommendations above, these systems will become an effective force multiplier for the warfighter.

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19. ABSTRACT
This report documents the results of a literature review in collective training for Battle Management Systems. Articles reviewed include experiments, interviews with experts, reports from implementation of Battle Management Systems, and psychological literature on learning and training. Recommendations for a collective training product are provided.