Ten Challenges for the Future of Computer Based Training

William Ferguson, Alice Leung, Bruce Roberts, David Diller
BBN Technologies
Cambridge, MA
wferguson@bbn.com, aleung@bbn.com, broberts@bbn.com, ddiller@bbn.com

ABSTRACT

A great many computer-based training systems are being built and experiments in new training techniques are being conducted, yet many critical questions remain unaddressed and appear resistant to current approaches. After tackling the research questions posed during DARPA's DARWARS program and spending years building training systems and developing techniques to meet particular training requirements, the authors felt that there were fundamental, cross-cutting challenges that needed to be met in order to make further progress toward delivering comprehensive training solutions. Our hope is that these challenges, if explicitly formulated and directly addressed, will provide a vision for the future of computer supported training. This short manifesto sets forth ten challenges, each of which could serve as the central focus of an R&D program:

1. Training Untrainable Skills – Training the intangibles: leadership, adaptability, resilience, or vigilance.
2. Practical, Collective Training – Training for large groups distributed in time and space.
3. Training to Learn – "Meta" training on the skills of acquiring expertise.
4. Keeping Training Current – Continually updating content.
5. Capturing and Transferring Experience – From the few to the many.
6. Training Each Other – Crowd-sourcing training; enabling peer training.
7. Training to Remember – Solving the skill retention problem.
8. Ubiquitous Training – Making training a natural part of task performance.
9. Persistent Mentoring – Providing career-long guidance.
10. Training to Excel – Pushing learners toward their top performance; aiming at excellence rather than training to standard.

In spite of some progress in addressing these items in the course of many different efforts, we contend that programs explicitly focused on these challenges would provide insight, progress and capability that will not be developed if we only continue with research on specific techniques, or the development of individual training systems.

ABOUT THE AUTHORS

William Ferguson is Lead Scientist at BBN Technologies with expertise in artificial intelligence, cognitive science, games and computer-based training. He played a principle role in the DARWARS project, a DARPA funded program to revolutionize computer-based training for the military by exploiting ideas and technologies developed in the commercial gaming world. DARWARS also conducted research and design in the technology of networked, experience-based teaching and learning. He served as Co-Principal Investigator for the Cultural Modeling Testbed, a joint DMSO/ARL/AFRL project to build a testbed for performing experimental research on culture and personality; especially with regard to their effects on team behavior. He was also co-principle investigator of a project called Helical training which attempted to transfer the experience provided by Alternate Reality Games into pedagogical use.

Alice Leung is a Senior Scientist at BBN Technologies. Her main research interest is the application of game-based technologies for shaping and measuring human behavior. She is currently working on a game-based experiential lookout trainer for the Navy and on a project to develop knowledge formulation systems that can be used by laypersons. Previously, she was a co-principal investigator for the JFCOM/DARPA Helical Training project to apply concepts from Alternate Reality Games to military training needs. She was also the technical lead on the DMSO/AFRL SABRE project to develop a game-based testbed for cultural behavior modeling and team performance research.

Bruce Roberts is a Lead Scientist at BBN Technologies, where he has developed numerous simulation-based intelligent tutoring systems: for Air Force technicians troubleshooting flight-line avionics, for conning officers practicing shiphandling in a virtual environment, and for Air Weapons Officers controlling air-to-air attack aircraft. He was the Principal Investigator for DARWARS architecture and integration, part of DARPA's Training Superiority program, and led the rapid development and successful deployment of DARWARS Ambush!, a widely deployed multi-player game-based training system. He is currently co-PI for VESSEL, an ONR project to deliver authoring tools and repeatable processes for developing game-based training for the Navy.

David Diller is a Senior Scientist at BBN Technologies in Cambridge, MA. He holds a B.S. in Computer Science and Psychology from Taylor University, an M.S. in Computer Science from Indiana University, and a joint Ph.D. in Cognitive Science and Cognitive Psychology from Indiana University. His current focus includes cognitive modeling, mixed-initiative agent-based systems, and simulation-based training applications. He has been involved in the development of a number of training systems, including DARWARS Ambush! – first as Technical Lead then as PI for a number of additional training domains and systems training (MOUT, Route Clearance, C-IED, CREW, Boomerang). He is currently PI on a joint AFRL/ARL/ARI effort to identify measures predicting expert IED detection performance utilizing DARWARS Ambush!. He was previously co-PI on a DMSO project developing a game-based testbed to study the impact of culture and personality on warfighters.

Ten Challenges for the Future of Computer Based Training

William Ferguson, Alice Leung, Bruce Roberts, David Diller
BBN Technologies
Cambridge, MA
wferguson@bbn.com, aleung@bbn.com, broberts@bbn.com, ddiller@bbn.com

INTRODUCTION

A look at the state-of-the-art in military training today shows steady advances in many aspects of this field. We see progress in pedagogical methods and technology, such as a growing emphasis on individual and team assessment, the increasing use of game-based technologies to boost training effectiveness and efficiency, and curricula that focus on adaptivity rather than memorization. Research into the physiological side of training has produced further understanding of neuro-cognitive processes, and identified possible agents for performance enhancement. Amid all these exciting developments, it is time to step back and look at the big picture. The training community needs to look harder at a number of fundamental challenges which deserve attention.

These challenges are fundamental in that they affect diverse training requirements and apply across many organizations. They underlie the current limitations in training in many domains, and for every level of learner from novice to master. Each of these ten training challenges raises deep, but often under-appreciated, issues. We offer our ideas and call on the training community and the researchers and designers who support it to devote more time, talent, and resources to meeting these challenges to revolutionize how training is created, delivered, and experienced.

Based on our research and development experience in immersive, computer-based training, we feel that these challenges are central to this community and relevant to the training community at large. We do not claim that these challenges constitute an exhaustive list of what should be explored. They also do not come from any attempt to assess current operational needs. Nevertheless, we hold that these challenges are currently underserved, and hold much potential as central foci for training research and development efforts.

CHALLENGES

Expanding Training Content

The first set of training challenges examines the gap between what we know how to train, and what people need to know. As DoD missions and the contexts in which they are executed become more complex, training must prepare the warfighter to meet a wider set of scenarios with a broader set of skills.

Challenge 1: Training Untrainable Skills
Anyone who works with Major Melissa Armesto has nothing but praise for the way she comes up with one good idea after another. Whether her unit needs a better way to schedule UAV operators or a catchy slogan for the softball team's T-shirts, people know to ask Maj. Armesto when they need someone to think outside of the box. Although she's tried to teach other people her knack for seeing new solutions, so far, Maj. Armesto has found this to be an untrainable skill.

There exists a cluster of high-level skills and abilities—often referred to as "soft" skills—that elude standard approaches to training. Calling them "soft" or "fuzzy" is meant to connote the difficulties associated with recognizing aptitude, identifying precursor skills, articulating progressive levels of expertise, and decomposing expertise into component skills that can be explained, measured and practiced effectively. Examples include leadership, creativity, adaptability, intuition or just plain common sense. Can we develop tools, techniques and pedagogical approaches for teaching these hard-to-define, hard-to-train skills? Can component skills be identified, prioritized, and trained to improve these high-level competencies?

Skills like leadership and adaptability are no longer considered the sole province of our senior leaders. Modern conflict has focused attention on the human dimension of training (TRADOC Pamphlet (Pam) 525-3-7-01) and has pushed responsibility for creative thinking, adaptability and leadership to lower and lower echelons. We therefore need training solutions that work not just at the war colleges but across the spectrum of military training. Contextually relevant forms of leadership training, for example, should be the norm rather than reserved for the exceptional few.

Compelling examples can be found for tackling these elusive skills but the effort must be made to understand their strengths and weaknesses, and to meld these initial successes into comprehensive, repeatable approaches.

Example: *Training Leadership* The Army Excellence in Leadership (AXL) project at the Institute for Creative Technologies exemplifies the case-based approach to promoting the acquisition of leadership skills. A thirteen-minute film, "Power Hungry," depicts a food distribution operation in Afghanistan and unfailingly provokes lively discussion about the conflicting motives and decisions by the principals portrayed. High production values and the instructional authoring effort make this approach expensive to replicate. Subsequent efforts to create a more interactive, immersive experience have not been so successful, demonstrating current limitations in simulation-based storytelling. Mateas and colleagues (Mehta et al., 2007) describe some techniques for remedying these limitations in order to support the richness and variety of user interaction needed to achieve successful virtual narrative. Challenge 5 in this paper, Capturing and Transferring Experience, describes alternative approaches for collecting and transmitting leadership expertise.

Example: *Training Adaptability* Gorman's Gambit (Weil et al., 2005) illustrates an approach to training for the unexpected. Simply put, it thrusts trainees into unusual situations where they are forced to adapt. It takes the view that a useful training approach is to remove the trainee from predictable surroundings, in this case thrusting a platoon of Soldiers into the fantasy role-playing game Neverwinter Nights™. In this environment, adaptability was critical to mission success. The trainees created tactics that effectively utilized the unique attributes of their characters and to marshal resources in novel ways – turning flying gryphons into unmanned aerial reconnaissance vehicles. It has also been shown that those trained with high diversity of instances will perform best at transfer, under novel conditions (Gonzalez and Quesada, 2003). Training under a diverse set of circumstances shows promise as a means of promoting adaptability.

Challenge 2: Practical, Collective Training

When a derailed train released 80 tons of chlorine, downtown North Adams, Missouri was at the epicenter of the disaster. The emergency response went well, but the subsequent evacuation and relocation of 10,000 residents, and protracted clean-up effort was criticized as chaotic and ineffective. "The National Guard wasn't talking to the police department, the Red Cross couldn't get the information they needed from the mayor's office, and the clean-up contractor didn't listen to FEMA," said a local official. "My office participated in a mass casualty drill just last year, but that didn't prepare us to handle a protracted disaster situation like this. Plus, many of the key groups we really needed to work with weren't even involved in that drill."

Collective training requires participants to be involved at the same time, often in the same place, and typically spans multiple echelons. Can these logistical impediments of time, space and scale be removed? In particular, the differing pace of action and class of decision-making (tactical, operational, and strategic) across echelons makes it difficult for all participants to remain fully engaged. Many military operations rely on "teams of teams" for mission success; yet much training focuses on individual or small team level tasks. Practical approaches for developing and executing training for large-scale, highly collective efforts will significantly improve the nation's ability to respond to both international and domestic crisis, from disaster relief efforts to combat campaigns.

Organizations such as JFCOM, DHS, and NATO regularly hold large-scale exercises which combine live and virtual simulations, allowing thousands of individuals across multiple agencies to train together over a period of days[1]. These multi-echelon, cross-agency exercises are considered the best way to determine readiness for an actual mission and the most efficient way to quickly train for a wide range of mission essential tasks. However, even with the reduction in exercise cost achieved by computer simulation, the remaining cost for planning, conducting, and participating in such events still requires a large resource investment. Thus, for most individuals, participation in a large-scale exercise is a rare opportunity. There is still a need to facilitate training teams of teams by making it easier to create, execute, and take part in this kind of collective mission and operation training.

While effective as a rehearsal for multi-echelon, cross-agency deployment, large-scale exercises are necessarily short and intense. They focus on a specific, high-intensity operation. This time-scale limitation precludes much opportunity for training in strategic or even operational decision-making. Instead, strategic decision-making is trained through simulated wargames with compressed time scales. While critical for giving high level staff a chance to practice and learn together, these kinds of exercises generally do not include participation from lower echelon leadership and outside organizations. Thus, participants are not able to train in

[1] NOBLE RESOLVE, PANAMAX, TOPOFF, and Patriot are some examples of such large scale exercises.

the relationship building and cross-organization coordination aspects of working with teams of teams. Novel types of training experiences are still needed to address the collective training needs currently unmet by large-scale exercises and wargaming.

Even if collective training can be effectively delivered to individuals from all military echelons and across international, federal, local, and non-government agencies, several inherent challenges of collective training will need to be met. These include (1) How can useful feedback and assessment be provided at an individual level when an exercise is focused on evaluating the performance of a team (or team of teams)? That is, how can individual contributions to a large-scale effort be assessed? (2) For effective performance, what fraction of the individuals from a future team of teams must have trained together previously? To what extent are individuals and small units interchangeable, within and across teams? The two priorities in research and development for practical, collective training are (1) enabling immersive, real-time training for weeks to months long operations, and (2) facilitating interagency and multi-echelon participation.

Challenge 3: Training to Learn

LTJG Mary Bonds has always been considered a "quick study," rapidly able to come up to speed in a new job. Her upcoming assignment to a Littoral Combat Ship will test her abilities. The Navy's desire to reduce manning will demand adaptable Sailors, who can quickly assimilate knowledge and skills.

Warfighters are always learning. However, most training focuses on specific content aimed at achieving mastery within a domain. Similarly, instructors are prized for their detailed knowledge and past experience. But what about learning as a skill of its own? Can we intervene deliberately to create better learners and trainers by focusing on the general skills and practices associated with superior abilities to learn and to train?

The payoff from focusing deliberately on training as a skill in its own right is well illustrated by the widespread adoption of the After Action Review (AAR) as an intrinsic part of military training exercises. The imperative and process for effectively leading an AAR is part of every leader's training, and the practice has become institutionalized across the services.

There is a vast literature on learning. The challenge is to apply those general principles in the specific context of military training. For example, the case method, widely used in teaching law and medicine, is implicit in any attempt to extract instructional value from lessons learned reports. The goals are the same: to use concrete examples of productive (and unproductive) ways of thinking about a situation, and to help the learner build a store of examples (cases) that can be used to guide one's actions in similar circumstances. Gonzalez (Gonzalez, Lerch, and Lebiere, 2003) articulates a theory of learning based on the recognition of instances as the basis for observed expert behaviors in dynamic decision making situations. This suggests that the deliberate organization of lessons learned to support instance-based learning holds promise for increasing the instructional value of this material.

Implicit in the use of cases as sources of instruction is the ability to apply the information contained in the case to new circumstances. This entails choosing an appropriate case and adapting its lessons to the new situation. These component skills require an ability to "see" or create analogies. Gentner and her colleagues (Thompson, Gentner, and Loewenstein, 2000) have demonstrated great success in explicitly teaching the use of analogy to better understand and reapply the lessons of case-based material. They report that graduate management students who drew an analogy from two cases were nearly three times more likely to incorporate the strategy from the training cases into their negotiations than were students given the same cases separately. In a different context, VanLehn (1998) describes the critical role analogy plays in making use of examples to solve physics problems.

Analogical thinking is a meta-cognitive skill. Another is generating explanations of one's own reasoning process. Can these skills be taught explicitly as a way of learning to learn? Although such instruction would take extra time, time away from domain-specific learning, the investment could be substantial if it produced warfighters better able to assimilate and retain new material rapidly and apply it in novel circumstances.

Better Training Development

The second set of challenges focuses on the process of developing and delivering good training. How can we acquire, record, and disseminate useful knowledge more quickly and less expensively?

Challenge 4: Keeping Training Current

During a weekend training session with his Army Reserve Unit, PFC M. Winters learned to inspect a vehicle for explosives or prohibited items. He reviewed the handouts, but still got a low passing score on the evaluation, because he missed finding a planted target. PFC Winters was worried. He knew that if he was deployed, manning vehicle checkpoints could be important. His sergeant, who had just returned from

active duty, told him not to worry too much because the training material didn't cover a lot of what he'd really need to know about manning checkpoints anyways. Determined to learn more, PFC Winters searched online and found plenty of advice written by people who claimed to be experts, plus a copy of the same handouts. But the 'experts' contradicted each other, some of the tips sounded ridiculous, and one writer hadn't even heard of the rank of staff sergeant. PFC Winters gave up after an hour, and decided to ask his sergeant for help next time there was a training exercise.

Keeping training current is becoming ever more important. This growing need is driven by the explosion in available information (both accurate and inaccurate), the requirement for military personnel at every rank to know more and think independently, and the increasingly rapid rate of change in technology and tactics. Yet these same factors slow down the speed at which training content can be developed, produced, vetted, and distributed through the traditional process.

Many aspects of the currency problem would be addressed by fundamental progress on some of the other nine challenges presented here. If experience can be captured and transmitted (Challenge 5), and this is done quickly, currency will be achieved. If a student becomes skilled at learning quickly (Challenge 3), then he may be able to compensate for out of date training materials by rapid on-the-job learning. If we can train each other (Challenge 6), then current knowledge can be disseminated through user created content, or by using field modifiable training materials.

Any process that radically speeds up the distribution of information will be disruptive to the parties who produce, vet, and consume that information. The crux of the currency challenge is how to maintain the quality of training content, both pedagogical and informational, while keeping life-cycle costs under control and significantly reducing turn-around time. Whether the solution will be to distribute the content evaluation process or to re-organize the traditional training providers to focus more on integrating with and rating content contributed by nontraditional authors, quality control is a central issue. If content creation is distributed, how will doctrine be set, and how will quality be maintained? Near-term research efforts into the challenge of keeping training current may include experiments in novel approaches to quality control.

Challenge 5: Capturing and Transferring Experience

First Lieutenant McKenna knew he had some critical information to share. His patrol had just been ambushed – and some of the tactics the enemy employed were unlike anything he'd seen before. 1LT McKenna fired up his laptop and loaded the virtual world his team used to rehearse missions. He found the street corner where he'd been ambushed, and quickly updated the virtual surroundings using automatic scene extraction from recent UAV video. Then he populated the scenario with avatars of the enemy, his team, and a few civilians, adjusting avatar behaviors to highlight the new tactics he'd observed today. At the next day's platoon leaders meeting, 1LT McKenna showed this virtual simulation and discussed the ambush. Later, his company commander suggested that he add a video diary of the experience and push it over to the lessons learned team So 1LT McKenna created a video introduction, added a voice-over to narrate the scenario, and then added a short debrief. Two days later he noticed the information from his experience was included in the weekly briefing, and a week later a professionally polished version of his scenario and video are featured on the lessons learned website.

Can the experiences of experts and novices be somehow captured and employed for training? Human beings inherently learn by doing; can they learn as naturally from the experiences of others? Can "lessons learned," "war stories," and storytelling in general be transformed into an effective instructional medium? How can storehouses of recorded experience be accessed for opportunistic use?

Given the rapidly changing requirements of today's military operations, coupled with the continual rotation of troops transitioning into and out of the theater, it is increasingly important that the experiences of troops be captured and disseminated for training. Currently, experienced troops are passing information back to units in the United States through a variety of channels, both formal and ad-hoc. The Services have set up organizations[2] to collect and disseminate lessons learned. However, the capture and transfer of experiential knowledge (wisdom that comes from experience) most often occurs through personal communications – war stories and lessons learned, told face-to-face, through email, or over the phone, and is not generally captured and widely disseminated. The ability to quickly capture these experiences and make them readily available to a wide training audience is an important capability for today's military. Technology (e.g., speech transcription, topic spotting, Web 2.0, etc.) is increasingly making it easier to capture, disseminate, and search through multi-media such as audio and video. Archives of lessons learned are being collected

[2] Center for Army Lessons Learned, Marine Corps Center for Lessons Learned, Navy Lessons Learned Program

and disseminated on sites such as the Army's CompanyCommand forums (Dixon, Allen, Burgess, Kilner, and Schweitzer, 2005). However, the creation of videos and their production into searchable and easily navigable material (e.g., ASK systems; Ferguson, Bareiss, Birnbaum and Osgood 1992), with pedagogical value approaching live story-telling, is difficult and time-intensive. Research in constructing narrative-based training systems from video interviews, and the development of such systems, would be of real value to the military.

Authorable simulation-based training provides another medium to impart experiential learning. DARWARS Ambush!, a game-based, multi-player convoy trainer (Diller, Roberts, Blankenship, and Nielson, 2004), had as one of its original goals the ability to provide a medium in which troops could share scenarios and lessons learned. In actuality, the sharing of lessons learned occurred more through the conversations between troops and scenario designers at training centers, who then implemented the scenarios, rather than direct scenario implementation by the soldier in the field.

The military will definitely benefit from the ability to quickly and easily bottle experiential knowledge (either through simulation and virtual worlds, and/or multi-media such as video) and transform it into effective, easily disseminated instructional materials. But, once it is possible to efficiently capture and transfer experience, other issues arise. How should content be vetted, filtered, or further refined? How can doctrinal control over training be maintained while making appropriate use of this new, and perhaps unvetted, content? In many cases these issues are the same as those facing online crowd-sourced information repositories such as Wikipedia[3].

Challenge 6: Training Each Other

When Captain J. Morrison suspected that one of the soldiers in his company was using drugs, he wasn't sure how to handle the situation. He knew what the official rules were, but this was the first time he had needed to apply them. CPT Morrison knew that he could rely on the CompanyCommand.army.mil leadership discussion forums for suggestions from people who had faced the same challenge. Over the next 48 hours, he received advice from commanders who had both successfully and unsuccessfully dealt with suspected code of conduct violations, as well as anecdotes from soldiers who had been mistakenly accused of wrong-doing. Several people referred him to an online management site offering case studies on how to handle tough discussions with employees, and a veteran chaplain pointed him to a set of video lectures on how to leverage peer pressure to uphold ethics standard, which she had made and posted to YouTube.

Besides learning by doing, people learn most naturally from each other. How can this process be leveraged and multiplied by the collective communication, dissemination, search and, aggregation capacities provided by the Internet?

Successful peer-driven learning has a number of benefits. First, it can provide informal training on the types of skills and knowledge that are mission critical, yet difficult to capture in formal documentation. For example, when working to develop good judgment for how and when to apply regulations and principles, much can be learned from other peoples' experiences. Second, because it makes relevant training content available very quickly, peer-driven learning can be a successful approach to address topics that undergo rapid change. For subject domains ranging from trouble-shooting the latest computer operating system to defeating insurgent improvised explosive device tactics, peers in the field can provide relevant information almost as soon as it has been discovered. Finally, teaching someone else is a good way to develop a deeper understanding. The experience of teaching can provide a continuing education for the teacher, as well as educating the students.

The military has always used peer-driven learning in face-to-face training, and has made significant progress in using internet resources to multiply training networks and form communities of practice. CompanyCommand.army.mil is a leading example of an online community of practice that provides invaluable and timely training content through peer contributions. Its success demonstrates how a number of the challenges of peer-driven learning can be met (Dixon et al., 2005). It has tackled issues such as how to (1) ensure that contributed content is accurate and high-quality, (2) help the user to quickly locate relevant content, and (3) cultivate sufficient community involvement in content creation and organization. Other web resource portals, such as Army Knowledge Online (AKO), provide quick access to officially produced training material, along with user discussion forums, but have not gone as far as CompanyCommand at encouraging peer authored content. Virtual World initiatives, like the Air Force's MyBase project, have been envisioned as a new way for learners to interact with training content, but peer-driven learning is not yet a focus of such efforts.

[3] Indeed, the Army has launched a pilot program to collaboratively write field manuals via wiki (New York Times, August 14, 2009)

A practical next step for expanding peer-driven learning for the DoD would be to study online DoD community sites for potential benefits that could be achieved through more user contributed training content and select one or more areas for expansion. Such a study would need to outline strategies for dealing with the associated community and content management challenges of peer-driven learning. Although CompanyCommand focuses on a peer and near-peer community, future efforts may also benefit from finding ways to involve other potential content contributors. Possibilities could include facilitating cross-service learning, engaging retired military personnel in mentoring activities, or taking advantage of digitized course content from civilian universities.

Making Training Work Better for the Student

Our final set of training challenges examines the trainee experience. These challenges focus on how training can become more integrated with job performance, and how participating in training can become easier and more effective from the learner's point of view.

Challenge 7: Training to Remember

Staff Sergeant Jones just received an unexpected call from his company training officer asking him to fill in as an instructor. Apparently he noticed SSgt Jones was qualified on several systems that needed to be taught as part of an introductory course. SSgt Jones was qualified on the systems, but he hadn't used them for several months, and was certainly not ready to teach a course on them. So he buckled down for a long couple of days brushing up on the material before the class, frustrated because this wasn't the first time the problem has come up. How can SSgt Jones keep current on these systems so he's not caught unprepared the next time?

A key element of training and education is the ability to teach knowledge and skills so that they will be retained for long periods of time (i.e., months or years). However, it is clear that memory for events declines over time – rapidly at first, and more slowly as time goes on. This forgetting curve has been long studied in psychology, going back to Ebbinghaus (1885/1964), and manifests itself as a basic law of human memory, consistent across a wide variety of types of tasks from memorization of simple word lists to performance on complex cognitive and motor skill tasks (Rubin and Wenzel, 1996). Performance decay is a fundamental problem for the U.S. Military, as recognized by two Defense Science Board Task Force reports (Chatham and Braddock, 2001, 2003). A substantial decrease in performance on complex military skills is seen in as little as one month after training, with performance often dropping to baseline levels within two to three months.

Research in learning theory and skill retention provides a number of insights. Unsurprisingly, retention is substantially improved by increasing the depth or quality of the learner's mental processing at the time of study (Craik and Lockhart, 1972). Additional learning or practice beyond initial successful completion (i.e., over learning or overtraining) has been shown to improve retention (Driskell, Willis, and Copper, 1992). In addition, improved knowledge of results (i.e., feedback) has been shown to improve learning (Hurlock and Montague, 1982), and thus retention. As mentioned in Challenge 10, Training to Excel, self-paced and individualized instruction can improve performance and learning efficiency. Studies have shown that better information retrieval occurs when the same contextual cues exist during both learning and retrieval (Tulving, 1983). This encoding specificity principle means in essence that the more the training context matches the operational context, the better performance in the operational setting will be. This is related to the concept of mnemonics for improved information recall, where information is connected to an established organizational structure at the time of learning, facilitating later recall.

Retention is also improved when practice is distributed over temporally spaced practice sessions. This distributed practice effect is a well-known finding in learning theory, with hundreds of studies having been performed, dating back to Ebbinghaus. However, in the majority of studies the information retention duration studied was a week or less – certainly much less than the retention durations desired for military skills. Studies which examined retention durations longer than one month (Bahrick, et al., 1993; Cepeda, et al., 2009) show that distributing learning over weeks or months is extremely beneficial to retention, as compared to concentrating learning within a single episode. There have been some attempts at creating and marketing computer software that utilize spaced repetitions for improving retention. These systems (e.g., SuperMemo[4]) are geared toward factual information, and have largely been utilized to aid language learning. Unfortunately, this finding is largely at odds with traditional training and educational practices.

Despite the extensive psychological research on learning and retention, there are still a large number of unanswered fundamental questions. For example, what are the optimal practice intervals for retention durations befitting real-world (non-laboratory) conditions? What

[4] http://www.supermemo.com/

is the appropriate profile for spaced training (i.e., uniform vs. expanding intervals)? What components of complex skills decay the fastest? Which contextual cues matter most for training specific tasks? How do the above-mentioned factors influence the training of complex motor skills as opposed to cognitive tasks? Finally, how are these findings best applied in practical situations where time for practice and training is limited, necessary knowledge and skills are dynamically changing, and the traditional paradigms for learning are largely institutional? Is it possible to conduct 'maintenance' training, as opposed to initial learning or refresher training? The chaotic nature of military requirements makes just-in-time training problematic, and the complex nature of today's military means it's impossible to train for all skills. How does one choose when, what, and how much to train? Research into the practical application of these findings is an important first step, since much of what is already known about improving retention is often overlooked or underutilized.

Challenge 8: Ubiquitous Training

Major Howard Lund, one week into his job as a Joint staff officer at MNF-I, has just been given the assignment to prepare for an important meeting with his State Department counterparts. He is trying to figure out who should attend, send out invitations, and schedule an online audio conference using the collaboration tool everyone seems to rely on. He has acquired the basics of sending and receiving email but hasn't had time to read through the entire user's guide for the collaboration software. What he would like is five minutes of focused instruction that will help him with the immediate task at hand, posting some read-ahead materials.

Training is commonly viewed as separate from work. It is time devoted exclusively to learning how to perform a task, acquiring the knowledge and honing the skills that will be called into play at another time and place. Our training institutions, personnel policies and ingrained learning habits conspire to define training as a dedicated activity divorced from the day-to-day, minute-to-minute, demands of the workplace. However, the increasing breadth of skills and adaptive responsiveness to novel situations we are coming to expect of tomorrow's warfighters are not well served by this separation. Can we instead develop training that is inextricably intertwined with performance: a natural, recurring, persistent aspect of work rather than a separate intermittent activity?

Achieving this goal will require changing the tools and technologies we depend on, to make them more supportive of ubiquitous training. Can equipment and software be designed so that using it naturally increases the user's expertise? Systems must become more aware of the tasks for which they are being employed, since training about how to use a system is most potent in the context of doing a job. The context provided by a user's tasks and goals should guide and focus the micro-training sessions implicit in the ubiquitous training model. This task context is necessary to ensure that the training is both timely and relevant. A user's intent—notoriously difficult to infer from user actions alone—should be expressible by the user in a form the system can understand.

Ubiquitous training implies giving the system some responsibility for observing and tracking task progress. How can we develop assessment technologies and methodologies that constantly and unobtrusively evaluate performance? Current work on adaptive interfaces, such as the use of biological and visual sensors to assess attention and flow (Kapoor and Picard, 2005), forms a starting point.

The time scale of ubiquitous training is much smaller than other forms of training. A training "session" may last only minutes or even second; e.g., as the system highlights where to look for a particular piece of information, explains how to interpret the information or demonstrates the consequences of a possible action. Some examples of ubiquitous training are so integrated with the actual task that they do not even require separate "sessions." In the simplest case, ubiquitous training may simply consist of providing feedback on a measure of interest. For example, hybrid cars that provide an instantaneous miles-per-gallon display can train drivers to accelerate and break slowly to improve gas mileage. This use of an operational system as the backdrop for training shares some aspects with the notion of embedded training; e.g., it inherits the burden of clearly distinguishing for the user between what is real versus hypothetical. But unlike conventional embedded training, ubiquitous training is not a separate mode of use but rather a pervasive functionality that is interleaved with normal operation. The time scale of ubiquitous training distinguishes it also from the notion of just-in-time training. The design of ubiquitous training emphasizes short training interactions just long enough to be useful without derailing the task at hand.

There are also social elements to creating a ubiquitous training environment. The tight integration of social networking and collaboration technologies with operational systems would facilitate the spontaneous sharing of expertise. With this approach the training comes not from the equipment or system itself but from the community of users. Mechanisms would exist for discovering other users (past and present), soliciting

their assistance, rapidly establishing communication, explaining the context of a question or impasse by sharing screens, and receiving guidance by temporarily transferring control while you watch and learn from someone else. Many of these capabilities can be found in collaboration tools available today. The challenge is to tightly integrate these capabilities with tools, systems and tasks external to the collaboration tool itself so that one can switch effortlessly and quickly between performing a task on one's own and effectively marshaling distributed sources of expertise on a moment's notice.

The principles of user-centered design (Roth, 2008) seek to address the challenge of building systems well matched to the needs of their user. The promise of ubiquitous training is to build systems that help you think like an expert, to know what to do in a situation as well as how to do it—by making training an aspect of everything we do, all the time.

Challenge 9: Persistent Mentoring

Major Marjory Green looked at her email and saw an automated message notifying her that she was due for a refresher course in Tactical Language Use and Cultural Sensitivity. As if she didn't have enough to do! She forwarded the email to her personal digital mentor (PDM). Perhaps she could just ignore this and no one would notice.

The next day, Maj. Green's PDM sent her email reminding her of a couple of tight spots her team had gotten into because of communication errors. The email also mentioned that two of her most trusted buddies from the academy had taken a relevant, simulation-based course and found it worthwhile. Finally, her PDM emphasized that this course would put her only one step away from finishing all the training she needed to be eligible for her next promotion, and provided the URL for downloading the necessary training module. Maj. Green shrugged, and then clicked to start the course. As usual the PDM had made things too relevant, too sensible and too easy to just let it slide.

One's ability, need, and desire to acquire and improve competencies vary over the course of a career. Habits and theories of self which are effective in one context may not work well in others. Mentoring is about helping people choose what and how to learn, and helping them execute and monitor their learning choices. Mentoring is not teaching per se, though it may be a source for learning about learning (See Challenge 3, Training to Learn) and for learning about oneself.

Typically, mentoring requires developing a trusting, knowledgeable and sometimes challenging relationship with a person that persists over time. Successful people cite mentoring as a key to their accomplishments, but good mentors may be too few in number, too hard to find, and the effort of maintaining the relationship may be too much for either the mentor or mentee to manage. Organizational approaches for making good mentoring available to every individual might include mentor training programs or policies to encourage and facilitate mentoring. Yet even in organizations with a strong culture of mentoring, such as the military, there aren't enough hours in the day to provide enough guidance to every member.

Artificial intelligence and internet communities are two intriguing approaches to supplement traditional one-on-one mentoring. We can envision software entities that could function as virtual mentors, automatically processing information about an individual's experiences, behaviors, and opportunities in order to provide guidance. People may be less defensive and more receptive when receiving suggestions from a computer. Kay & Kummerfeld (2009) articulate the challenges for maintaining user models that persist and guide personalized mentoring. Another alternative might be to form enduring distributed online communities, enabling participants to collectively fill the role of life-long mentor for each other. Instead of an individual relationship with a single mentor, each member would have a relationship with the collective community. As a whole, the community would offer a broader set of life experiences and expertise than a single mentor could provide. Technology could provide tools to make traditional one-on-one human mentoring relationships more effective and normative, providing a "force multiplier" for a mentor's efforts.

Widespread mentoring is a need that most of the training community can agree on. This need is becoming more acute as people's careers become more volatile and everyone has less time for deep relationships that are separate from their family or current work context. Furthermore, as people experience professional changes more frequently, it is harder for a human mentor's depth of experience to stay relevant. We foresee near-term progress on this challenge through self-mentoring developments within learning management systems and an increasing role for collective mentoring within online communities of practice (related to Challenge 6, Training Each Other).

Challenge 10: Training to Excel

Sergeant Dirk Murphy has been on guard duty for eight hours and he is doing fine. Ordinarily a commanding officer would have to be desperate or foolish to leave a man on guard duty that long, but Sgt. Murphy's special aptitude for vigilance was discovered in simulation-

based testing when he first signed up for the Army. Since then, he's had many opportunities to train and improve this special ability to focus his attention over long periods of time. Nothing gets past him; he never gets bored. He just has the kind of mind that never wanders and he, his commanders, and teammates all know this. Sgt. Murphy is doing his job, a job he performs exceptionally well.

Instead of pushing each person to achieve their personal best at each skill, most current training programs allow an individual to stop working towards improvement once they can perform to a standard level. Aggregated across many individuals and many skills, an organization misses a potentially large performance increase when it settles for normative competence.

Self-paced training is often considered an appropriate way to accommodate both fast and slow learners. While this is a step towards individualized training that can help each learner achieve their potential, it does not allow for the many distinct training approaches which may be necessary to nurture excellence. For example, a student with a quick intuitive grasp of arithmetic may need a curriculum that includes a variety of challenges ranging from real world engineering problems to abstract number theory to improve their skills, but may become bored with a traditional self-paced training module based on drill and practice, regardless of how quickly he or she can proceed through it.

The approach of training to standard also incurs the risk that the standard (1) is not high enough, or (2) does not adequately describe the complete task. Simulation-based training can be an effective way to train for excellence when it gives learners an opportunity to practice a complete task in increasingly demanding scenarios. Training to Excel may also be part of the solution for Challenge 7, Training to Remember, because training to exceed a standard would create a buffer against skill decay.

CONCLUSION

In this paper, we identified critical, universal, and under-examined issues in the dissemination of knowledge. We imagined how new immersive simulation technology, authoring technology, global interactive media and Internet social structures, and exponential growth in information availability could be exploited to prototype and explore fundamentally new solutions to training challenges. Many of these cutting-edge explorations will fail, but those that succeed will further understanding and lead to new high confidence, reproducible approaches that can be routinely applied.

But another question is what needs to change in order to produce these kinds of explorations. We believe that the area of training needs more "inventors." In other disciplines, there are researchers who are guided by the empirical, scientific method of inquiry and engineers (practitioners) who design and build things that work reliably. But, there are also inventors, who serve an in-between role. Inventors try many approaches to solve important problems in new ways. They fail a lot, and spend a lot of time at the drawing board, but they play a key part in making tangible progress.

There may be several reasons why there are so few training inventors. While experimental physical devices can often be tested in an environment where they cannot do damage, testing training processes necessarily involves people. People can be taught misconceptions, become confused, or their time can simply be wasted and their ignorance left intact. These possibilities certainly need to be responsibly minimized by training innovators.

Furthermore, the stake-holders in training development may be implicitly discouraging the invention process. Researchers seek measured, reproducible results backed by theory; practitioners need large scale applicability, and funders demand that specific targeted skills be the focus of most training endeavors. There are good reasons for each of these concerns, but the net result may be holding back progress in new training methods and technologies.

We are not suggesting that we should stop trying to measure training effectiveness or that we cannot make incremental progress using existing methods. But the pendulum may be swinging toward conservatism (perhaps because of recent over-hyping and misapplication of virtual world technology.) We see an opportunity for radical change in training technology and invite training researchers, funders, students, practitioners, educators and most of all inventors and innovators to focus on the fundamental possibilities for progress. We need new kinds of people to teach new things in new ways. Progress can only be made if we focus our attention on key challenges, such as the ten described here.

REFERENCES

Bahrick, H. P., Bahrick, L. E., Bahrick, A. S., & Bahrick, P. E. (1993). Maintenance of foreign language vocabulary and the spacing effect. *Psychological Science*, *4*, 316–321.

Cepeda, N. J., Coburn, N., Rohrer, D., Wixted, J. T., Mozer, M. C. & Pashler, H., (2009). Optimizing distributed practice: Theoretical analysis and practical implications. *Experimental Psychology*, *56*, 236-246.

Chatham, R., & Braddock, J. (2001). *Training superiority and training surprise* (Defense Science Board Task Force Final Report). Avail online www.dtic.mil/ndia/2001testing/chatham.pdf

Chatham, R., & Braddock, J. (2003). *Training for future conflicts* (Defense Science Board Task Force Final Report). www.acq.osd.mil/dsb/reports/tfc.pdf

Craik, F. & Lockhart, R. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning & Verbal Behavior*, *11*, 671-684.

Diller, D. E., Roberts, B., Blankenship, S., & Nielson, D. (2004). DARWARS Ambush! – Authoring Lessons Learned in a Training Game. In *Proceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2004*, Orlando, FL, December 2004.

Dixon, N., Allen, N., Burgess, T., Kilner, P., & Schweitzer, S. (2005). *CompanyCommand: Unleashing the power of the army profession.* West Point, NY: Center for the Advancement of Leader Development & Organizational Learning.

Driskell, J.E., Willis, R.P. & Copper, C. (1992). Effect of overlearning on retention. *Journal of Applied Psychology*, *77*, 615-622.

Ebbinghaus, H. (1964). *Memory: A contribution to experimental psychology* (H. A. Ruger, C. E. Bussenius, & E. R. Hilgard, Trans.). New York: Dover Publications, Inc. (Original work published in 1885).

Ferguson, W., R. Bareiss, L. Birnbaum and R. Osgood ASK Systems: An Approach to the Realization of Story-Based Teachers. *Journal of the Learning Sciences*, vol. 2, no.1. 1992.

Gonzalez, C. (2005). Task workload and cognitive abilities in dynamic decision making. *Human Factors*, *47*, 92-101.

Gonzalez, C., Lerch, J. & Lebiere, C. (2003). Instance-based learning in dynamic decision making. *Cognitive Science, 27*, 591–635.

Gonzalez, C., & Quesada, J. (2003). Learning in dynamic decision making: The recognition process, *Computational and Mathematical Organization Theory*, *9*, 287-304.

Hurlock, R.E., & Montague, W.E. (1982). *Skill Retention and Its Implications for Navy Tasks: An Analytical Review* (NPRDC Special Rep. No. 82-21) San Diego, CA: Navy Personnel Research and Development Centre.

Kapoor, A. & Picard, R. (2005). Multimodal Affect Recognition in Learning Environments. *Proceedings of the 13th Annual ACM International Conference on Multimedia*, 677-682.

Kay, J. & Kummerfeld, B. (2009). Lifelong User Modelling Goals, Issues and Challenges. *Proceedings of the Lifelong User Modeling Workshop at UMAP'09 User Modeling, Adaptation, and Personalization*, pp. 27-34.

Mehta, M., Dow, S., Mateas, M. & MacIntyre, B. (2007). Evaluating a Conversation-Centered Interactive Drama. In *Proceedings of the Sixth International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS)*, Honolulu, Hawaii, USA. May 14-18, 2007.

Roth, E. M. (2008). Uncovering the Requirements of Cognitive Work. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 50,* 475-480.

Rubin, D. C. & Wenzel, A. E. (1996). One hundred years of forgetting: A quantitative description of retention. *Psychological Review*, *103*, 734–760.

Stickgold, R. & Walker, MP. (2007). Sleep-dependent memory consolidation and reconsolidation. *Sleep Medicine*, *8*, 331-343.

Thompson, L., Gentner, D. & Loewenstein, J. (2000). Avoiding Missed Opportunities in Managerial Life: Analogical Training More Powerful Than Individual Case Training. *Organizational Behavior and Human Decision Processes*, *82*, 60–75.

TRADOC Pamphlet (Pam) 525-3-7-01, *The U.S. Army Study of the Human Dimension in the Future 2015-2024*.

Tulving, E. (1983). *Elements of episodic memory*. Oxford: Oxford University Press.

VanLehn, K. (1998). Analogy events: How examples are used during problem solving. *Cognitive Science, 22*, 347-388.

Von Hippel, E. (2005). *Democratizing Innovation*, Cambridge, Massachusetts: MIT Press.

Weil, S. A., Hussain, T. S., Brunyé, T. T., Ferguson, W. Sidman, J. G., Spahr, L. L., & Roberts, B. (2005).. Assessing the Potential of Massive Multi-Player Games to be Tools for Military Training. In *Proceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2005*, Orlando, FL, December 2005.