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and Dee H. Andrews

Accelerated Expertise

Training for High Proficiency in a Complex World

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Development Center, University of Pittsburgh, from 1978 to 1982. He was a Professor in Medical Education and Psychiatry (honorary) at Southern Illinois University School of Medicine, 1982–2001. He has conducted research on expert-novice differences in complex cognitive skills; conceptual understanding and misunderstanding for complex knowledge; and novel means of instruction in complex and ill-structured knowledge domains. Since joining IHMC, he has been investigating (with Jeff Bradshaw and others) coordination, regulation and teamwork in mixed groups of humans and intelligent software agents (including robots). He is co-editor of *Expertise in Context*, *Smart Machines in Education*, and the *Cambridge Handbook on Expertise and Expert Performance*.

Lia DiBello is the CEO and director ofresearch at WTRInc., a cognitive sciences research firm that develops products for enhancing business decision-making. She is known for innovative (non-verbal) methods of assessing skill and business judgment among executives. She is the innovator behind the FutureView(tm) Profiler, which has been recognized as a theoretical and methodological breakthrough in knowledge elicitation, and was awarded an Innovative Technology Award by TechAmerica in 2008. DiBello is best known for the development of a particular kind of activity-based "strategic rehearsal exercise" approach that has been shown to greatly accelerate learning through cognitive reorganization. In addition to her applied work in industry, Dr. DiBello has authored numerous journal articles, book chapters and presentations and has taught several courses on the development of expertise, technology deployment and design, and accelerated organizational change as a Visiting Professor at the University of California San Diego. She is frequently invited as a speaker at conferences and professional meetings.

Stephen M. Fiore, Ph.D., is President of the Interdisciplinary Network for Group Research and faculty with the University of Central Florida's Cognitive Sciences Program in the Department of Philosophy, and Director of the Cognitive Sciences Laboratory at UCF's Institute for Simulation and Training. He maintains a multidisciplinary research interest that incorporates aspects of the cognitive, social, organizational, and computational sciences in the investigation of learning and performance in individuals and teams. As Principal Investigator and Co-Principal Investigator, he has helped to secure and manage over $20 million in research funding from organizations such as the National Science Foundation, the National Aeronautics and Space Administration, the Office of Naval Research, the Air Force Office of Scientific Research, and the Department of

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Homeland Security. He is co-editor of recent volumes on shared cognition (2012), macrocognition in teams (2008), distributed training (2007), team cognition (2004), and he has co-authored over 100 scholarly publications in the area of learning, memory and problem solving at the individual and group level.

Dee H. Andrews received his Ph.D. in Instructional Systems from Florida State University. He is currently a Senior Research Psychologist with the Army Research Institute for the Behavioral and Social Sciences in Mesa, Arizona. Prior to this he served as the Senior Scientist (ST) for Training Psychology for the Air Force Research Laboratory in Mesa, Arizona. He also held the position of Division Technical Director for the Warfighter Training Research Division of the Air Force Research Laboratory, and Senior Research Psychologist for the Army Research Institute for the Behavioral and Social Sciences in Orlando, Florida. He is a Fellow in the Human Factors and Ergonomics Society, the American Psychological Association, the Royal Aeronautical Society of the United Kingdom, and the Air Force Research Laboratory. His research interests include cyber training, learning organizations, simulator design, flight training, advanced distributed learning, accelerated learning and distributed mission training.

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Preface

The impetus for this book was a tasking from the Defense Science and Technology Advisory Group (DSTAG), which is the top-level Science and Technology policy-making panel in the Department of Defense. They were concerned about the complex issues that faced US and Coalition Forces in the wars in Afghanistan and Iraq. Junior officers and enlisted personnel were facing missions and tasks that our military had not had to face since the war in Vietnam, tasks such as counter-insurgency warfare and temporarily governing villages. During the Cold War, military personnel could typically count on being assigned to one location for at least three years before rotating to the next. That era allowed for robust continuous training while at a duty station. However, in the current era of frequent deployments to a variety of locations worldwide to fight the War on Terror, there are far fewer opportunities to have systematic training and practice. These are highly dynamic tasks that require considerable cognitive flexibility. Speed in acquiring the knowledge and skills to perform the tasks is crucial, as the training must often be updated and provided shortly before the personnel must deploy to the theaters where the wars are being fought.

Yet, it still ordinarily takes many years to achieve proficiency. The tasking from the DSTAG asked that the construct of accelerated learning be defined, and its provenance described. This would include a review of the research literature on learning acquisition and retention. This volume resulted from two workshops sponsored by the US Office of the Director, Defense Research and Engineering and the Department of Defense (DoD) Accelerated Learning Technology Focus Team (July 2008; October 2009). Through the auspices of the US Air Force Research Laboratory, these workshops brought together leading academic, private sector, and DoD specialists in areas of training and expertise studies. The objective was to create a design and roadmap for investigations aimed at developing robust and broadly applicable methods for:

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1 Accelerating the achievement of high levels of proficiency (i.e., expertise)
2 Facilitating the retention of knowledge and skill.

A specific problem that motivated these efforts was that military personnel are required to take a hiatus from their primary domain of expertise in order to fulfill other military requirements. A hiatus can take many forms, such as staff duty, teaching at a military academy or in Reserve Officer Training Corps programs, or taking courses of study at military or civilian institutions of higher education, a hiatus can last from a few weeks to as long as four years. During a hiatus it is often not possible to train or practice in the primary domain of expertise. While such hiatuses may be relatively unique to the military, there is a more pervasive and non-trivial problem that is experienced, often frequently, by individuals in all walks of life: prolonged periods of inactivity in a domain of expertise—where a high level of proficiency is required—followed by the expectation that those same individuals can simply pick up where they left off without detriment. In the context of this hiatus problem, attendees at the workshops focused on addressing the following proficiency and accelerated learning goals. These goals were originally discussed in the context of the types of problems faced by United States Air Force (USAF) personnel specifically. In this volume we tap into the USAF examples, but we address these goals more broadly:

- How can we develop operational definitions and measures of proficiency at a fine grain?
- How can we develop methods for identifying expert mentors and revealing their knowledge and strategies?
- How can we best design training to promote skill retention and prevent skill decay during periods of hiatus?
- How can we train for adaptivity and the need to cope with the ever-changing workplace and changing and challenging activities?
- How can we train for resilience and the need to cope with complexity when unexpected events stretch resources and capabilities?
- Which military and private sector jobs require high levels of proficiency?
- How can we construct optimal strategies for mitigating at least some skill decay while on a long-term hiatus?

Responses to these questions supported the formulation of guidance

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for attempts to accelerate the achievement of proficiency

As we responded to the DSTAG tasking, it became clearer how accelerated learning concepts apply broadly. The world in general, and economies specifically, are becoming more complex, and new learning must be absorbed at ever increasing rates if organizations are to keep up with the changes. The learning required in many fields will not be acceptable if learning rates progress at traditional speeds. A major part of the definition for accelerated learning must include effectiveness as well as an understanding of the need for retention of skill and knowledge. Clearly, it does no good to accelerate the rate of learning if that learning cannot be retained and effectively used on the job. Our hope is that readers of this book will gain a better understanding of what is known about accelerated learning and what needs to be discovered to improve attempts to speed learning along.

There would be great advantages if regimens of training could be established that could accelerate the achievement of proficiency. There is reason to hypothesize that the achievement of proficiency can be accelerated, and this volume presents specific plans and roadmaps for attempts to do so—using both military and non-military exemplar case studies. It is likely that methods for acceleration will leverage the technologies and capabilities including virtual training, cross-training, training across strategic and tactical levels, and training for resilience and adaptivity.

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Series Editor's Preface

The previous title in the Expertise Series was *Informed by Knowledge: Expert Performance in Complex Situations* edited by Kathleen L. Mosier and Ute M. Fischer. That volume was formed around the proceedings of the 8th International Conference on Naturalistic Decision Making, which was held in 2007. The present volume is authored but represents a synthesis of meetings, on the topic of "accelerated expertise." The roster of authors includes Stephen M. Fiore, who organized the 10th International Conference on Naturalistic Decision Making, and has made a number of significant contributions to the field of expertise studies; and Paul J. Feltovich, one of the founders of the field of expertise studies. These authors have collaborated with applied scientists in the writing of this volume. Lia DiBello has pioneered methods for adapting methods and theories from the field of expertise studies to the challenges of training for cognitively-intense jobs. Dee H. Andrews served in an illustrious career as Senior Research Psychologist (Training Psychology) for the U.S. Air Force. The second author, Paul Ward, has a specialization in the area of sports expertise, where training, coaching, and the achievement of high proficiency are a primary research focus. Paul is also welcomed as the newest member of the Series' Board of Editors.

As always, the Board invites the submission of prospecti for titles, including authored and edited books, that address concepts, research, and applications in Expertise Studies.

Sabine M. Sonnentag
University of Mannheim
Germany
November 2012

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We also acknowledge the contributions of all the scientists who participated in the two AFRL sponsored workshops on Accelerated Learning: Herb Bell (AFRL), Wink Bennett (AFRL), CDR Sean Biggerstaff (OSD-ATL), Jeff Bradshaw (Institute for Human & Machine Cognition), Rodney Chapman (Naval Service Training Command), Neil Charness (Florida State University), Paul Chatelier (Potomac Research Institute), Ray Clifford (Brigham Young University), Joseph Cohn (Defense Advanced Research Projects Agency), Michael Dekle (Naval Education and Training Command), Paula Durlach (Army Research Institute), Chris Earl (Defense Advanced Research Projects Agency), Kelly Ellis (AFRL), Katherine Ely (Advanced Distributed Learning DoD), Anders Ericsson (Florida State University), Pat Fitzgerald (AFRL), Dexter Fletcher (Institute for Defense Analyses), Robert Foster (OSD-ATL), Jared Freeman (Aptima, Inc.), Andy Gibbons (Brigham Young University), Kevin Gluck (AFRL), Steve Goldberg (Army Research Institute), Frank Greitzer (Pacific Northwest National Laboratory), Alice Healy (University of Colorado), Maj Brian Healy (United States Air Force), Lt. Col. Gina Hilger (United States Air Force), Robert Hubal (RTI International), Gary Klein (Klein Associates Division ofARA, Inc.),

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The Value of Expertise and the Need to “Capture” Knowledge

Overview

The purpose of this book is to provide information for anyone interested in the concept or phenomenon of “accelerating learning”—anyone in education, training, psychology, academia in general, government, military, or industry. We take the concept of skill development to the limit.

The first two chapters cover the concept of accelerated learning and different senses of accelerated learning (Chapter 2), and the notion of a proficiency scale, spanning trainee to expert levels of knowledge and skill (Chapter 3). The next three chapters (4-8) cover the main findings and theories from research on practice and the role of feedback, on transfer of training, on retention and decay of knowledge and skill, on problem-based training, and on team training. Our summaries of these literatures from psychology, education and training are just that—summaries. More could not be expected of any single book, though we have tried to be as comprehensive as practicable. Chapter 9 discusses some projects that can be understood as actual, successful demonstrations of accelerated learning, in some cases to high proficiency levels. We abstract some generalizations from those demonstrations, and use them along with conclusions from the literature reviews, in the following chapters (11-15). We present a theory of expertise and high-end learning that might be useful in framing accelerated learning concepts and research. We discuss the research challenges for any attempt to demonstrate or study accelerated learning. We provide a roster of the skills and capabilities that must be instilled for accelerated learning to high proficiency levels. We discuss the nature of the materials and teaching strategies

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that would be required for successful accelerated learning, and then we conclude with a notional roadmap for projects on accelerated learning to high proficiency.

We begin with a discussion of why accelerated learning—especially accelerated expertise— is more than a concept or phenomenon. It is a pressing societal need.

Workforce Issues

In recent years there has been wide recognition in the business community of the importance of knowledge capture, preservation, and sharing in knowledge-based organizations. Largely this is in response to the coming "grey tsunami"—the imminent retirement of senior experts in business and government (see Hoffman & Hanes, 2003; Moon, Hoffman, & Ziebell, 2009). Many organizations (e.g., DoD, NASA, the electric utilities) are at risk because the impending absence of soon-to-be-retired yet highly skilled domain practitioners may result in inadequate preparation for how to deal with some of the most difficult and mission-critical challenges (Hoffman & Hanes, 2003). A number of recent books, both edited and authored, both academic and popular press, have discussed the training issues and workforce challenges that have emerged as organizations have become more "knowledge-based" and technologies more pervasive in shaping complex cognitive work (e.g., Davenport & Prusak, 1998; Ericsson, 2009; Goldstein & Ford, 2001; Kraiger, 2001; Nonaka & Takeuchi, 1995; O'Dell & Grayson, 1998; Quiñones & Ehrenstein, 1996). The modern workplace has been dubbed "sociotechnical" in recognition of the fact that the work involves collaborative mixes of multiple people and multiple machines (Collins, Brown, & Newman, 1989; Druckman & Bjork, 1991; Hoffman & Militello, 2008). This characterizes both military and civilian work settings and activities.

Domain practitioners who achieve high levels of proficiency provide technical judgment to speed decision-making in time-critical events. They provide resilience to operations by resolving tough problems, anticipating future demands and re-planning, and acting prudently byjudgment rather than by rule. High proficiency practitioners exercise effective technical leadership in ambiguous or complex situations, often by communicating subtle features that other people will not see until they are pointed out. Often they are also the ones who understand the history, the interdependencies of units and processes, and the culture of their complex organizations—knowledge that is often essential in actually "getting things done" (e.g., Stein, 1997).

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As workplaces and jobs become more cognition-intensive, organizations need to take traditional notions of training to new levels, and well into the territory of complex systems. Workers in sociotechnical systems must be trained to be adaptive, so that they can cope with the ever-changing world and ever-changing workplace. People must be trained to be resilient, so that they can cope with complexity when unexpected events stretch resources and capabilities. And workers must be trained faster. Intelligent systems technology, and intelligent use of technology, will certainly play a critical role in this.

In the following section we use the changing face of the military, the evolving nature of the work carried out by military personnel, and the changing demands of this work to highlight some of the implications for developing effective training for achieving proficiency in this and other sociotechnical domains.

Training to High Proficiency

Training for the achievement of expertise has become a salient topic for discussion at research and technology meetings, often sponsored by military branches interested in these issues (e.g., Hszieh, Shobe, & Wulfleck, 2009). Many current jobs (estimated at 85 percent in a military context) can be trained through established methods, and those jobs involve tasks that can be performed by individuals who are proficient (Wulfleck & Wetzel-Smith, 2008). In classical guild terminology, they would be "journeymen"—they have practiced to the point where they can perform their duties unsupervised (literally, they can go on a journey). In many sociotechnical domains, there is a need for personnel who are trained at a number of levels of proficiency. While there may be some requirements for more senior experts in select areas, there is a more profound and continuing need for journeymen and senior journeymen to carry out the complex cognitive work effectively to ensure current and future success.

One reason is the constantly changing nature of work and the various jobs involved in completing that work (Quiñones & Ehrenstein, 1997). Furthermore, jobs must be adaptive to constantly changing circumstances or even threats. In a sense, everything is getting more complex and important work is often *cognitive* work (Wulfleck & Wetzel-Smith, 2008). Across recent decades, many workplaces have changed, and many new ones emerged, as forms of complex sociotechnical systems in which the work is cognitive and collaborative, and heavily reliant on computer technology. Work in such domains requires high levels of proficiency, in terms of

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knowledge, reasoning skill, and critical thinking skill. In a military context, for instance, specific domains include command posts, intelligence analysis, emergency response, disaster relief, and cyberdefense. The required preparedness status for these and other similar sociotechnical domains includes capabilities to be adaptive, resilient, and robust in the face of unexpected disruptions. This is now referred to as "cognitive readiness" (Morrison & Fletcher, 2002).

Many career paths involve training to proficiency (often, high levels of proficiency) and then reassignment for some period of time (sometimes three or more years) at some other job. This is frequently termed a "hiatus." The classic military example is that of a pilot, trained to proficiency and tested in combat, and then assigned to duty at the Pentagon for a limited period. Temporary reassignment is commonplace (particularly in the military, and in private sector settings, such as when temporarily shifting between job roles or between work activities). This raises numerous issues in the general area of training, specifically issues of transfer, decay, and retention of knowledge and skill.

While many jobs can be trained through established methods, and such tasks can be performed by journeymen, highly proficient personnel are needed to perform domain specialist tasks (e.g., Military Warrant Officer). The bottleneck for producing such critical individuals is that it has typically taken many years of experience and deliberate practice for individuals to master their domains (e.g., see Ericsson et al., 2006). Over and over, research in the field of Expertise Studies has shown, in diverse domains from medicine to firefighting, that it takes years of extended training and experience to achieve high levels of proficiency. Reasons for this include domain complexity, irregularity across encountered cases, the need for deliberate practice, and the need for practice at tough cases—which may not be frequent in the normal course of work—to stretch the current skill level.

To elaborate on the military example further, the challenge of learning is compounded by such practices as collateral assignment, frequent redeployment (e.g., rapid skill decay on the part of pilots creates a need for expensive re-training), inadequate or ad hoc mentoring, and the drive for "just-in-time" training. Another significant challenge is clustered around career (versus job) training, and expertise retention. Professional Military Education, such as that offered by the various war colleges, is an example of career training, in which personnel learn about operational and strategic warfighting issues. The entire field of "knowledge management" is formed around the notion of preserving and sharing expertise (e.g., Becerra-Fernandez et al., 2004).

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Transfer of Training and Knowledge

Transfer, or the ability to use knowledge flexibly and effectively across application areas, is an important component of proficiency. In a large respect, accelerated learning means improving transfer (and retention) capability. The major theory of transfer in learning is the "common elements" theory (e.g., Thorndike & Woodworth, 1901). Based on this idea, one would say that training should minimize the transfer distance from training to workplace. Recent research is suggestive of the conditions that promote transfer, such as the judicious use of particular kinds of process and outcome feedback (Schmidt & Bjork, 1992). However, performance issues go beyond transfer from the classroom to the operational context. Simply "working at a job" does not promote progression along the proficiency continuum (e.g., Feltovich, Preitula, & Ericsson, 2006). Unless there is continuous deliberate practice and feedback on difficult tasks or, at the very least, recurrent engagement in activities that will maintain the current level of skill, the only thing one can do "on the job" is forget and actually experience skill degradation.

Furthermore, the current challenges for training involve two different sorts of transfer. One is transfer across situations. An example would be an infantry commander, who knows how to conduct traditional warfare but is asked to develop tactics for an insurgency operation. The second challenge is transfer across responsibilities. An example would be a warfighter having a skill at maintenance of an F-16 engine who is promoted to a supervisory position. Since different skill sets would be involved, one would need to train for the new role, and not just assume that previously developed skills would transfer (or even be applicable) and constitute a sufficient basis for success in the new role. When a journeyman or expert moves from one job—where domain expertise is all that is required of them—to a supervisory job, there is an extra challenge because they are still expected to maintain their domain competence while also acquiring and performing their new supervisory duties at a level above the required threshold of proficiency.

Knowledge Management

The concept of accelerated learning has been implicit in discussions of the concept of the "expert apprentice." The idea here is that knowledge management depends on having a workforce of proficient knowledge elicitors who are trained to be able to rapidly achieve the level of understanding of an advanced apprentice, minimally. Only by acquiring domain knowledge at that level can they contribute

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substantively to processes of capturing and preserving expert knowledge (Militello & Quill, 2007). The field of Knowledge Management has a theme of accelerated learning, which is not surprising given the business incentives to train faster and better. One goal, for instance, is to reduce "time to value" in product innovation. Indeed, the field of Knowledge Management has focused on issues of learning and training. This is shown by the emergence of the roles of Chief Knowledge Officer and Chief Learning Officer, and is reflected in magazine articles having titles such as "Learning at Top Speed" (Atkinson & Barry, 2010).

The early work on "expert systems" led to the vision that organizations might create large knowledge repositories (Becerra-Fernandez & Leidner, 2008). Knowledge Management software systems differ from traditional information management systems in that Knowledge Management software tools help create the very content on which they operate. Like traditional information management systems, however, there are issues of acceptance and integration into business procedures and organizational cultures.

Over the years since Gary Klein's seminal paper on preserving corporate knowledge (1992), numerous articles and trade books have appeared bearing such titles as: *If we only knew what we know* (O'Dell & Grayson, 1998) and *The knowledge creating company* (Nonaka & Takeuchi, 1995) (see also Allee, 1997; Brooking, 1999; Choo, 1988; Davenport & Prusak, 1998; Lambe, 2007; Leonard & Swap, 2005). All of these discuss expertise (or "core competencies"), knowledge elicitation and knowledge repositories. These books illustrate what some see as the knowledge management craze of the late 1990s, when upwards of 25 percent of Fortune 500 companies had a Corporate Knowledge Office (Pringle, 2003). Organizations such as IBM and the World Bank have made substantial investments in support of organizational knowledge capture and management. Norman Kamilkow, Editor of *Chief Learning Officer Magazine* said,

> What we saw was that there is a growing role for a chief learning officer type within enterprise-level companies … there is a need to have somebody focused on how to keep the skills of the corporation's work force at a high level.
>
> (quoted in Pringle, 2003, p. B1)

In the Knowledge Management process, company management establishes a program whereby experts who possess valuable undocumented knowledge collaborate with a knowledge engineer. Working together, they elicit the worker's wisdom for inclusion in the

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organization's knowledge base. In extreme cases, such as a senior worker retiring, the individual might be retained or brought back as a consultant (Becerra-Fernandez & Leidner, 2008).

The field of Knowledge Management raises the practical problem of knowledge finding; identifying individuals who possess knowledge that is:

1 Unique to them,
2 Critical to the organization, and
3 Tacit in the sense of being undocumented.

This has been recognized as a key to the success of Knowledge Management broadly (Gaines, 2003; Gross, Hanes, & Ayres, 2002; Hanes & Gross, 2002). Recent experience shows that it is possible and sometimes fairly easy for experts and managers, working together, to identify the unique and important knowledge areas in which a particular expert excels. Likewise, domain practitioners can readily identify those important concepts in a domain that seem to be especially difficult for others to fully comprehend (Dawson-Saunders et al., 1990). A critical gap, however, is that a robust, general procedure for doing this has not been formulated in such a way that anyone might implement it.

Knowledge-intensive organizations rely on decision-makers to produce mission-critical decisions based on inputs from multiple domains (Becerra-Fernandez et al., 2004). The decision-maker needs an understanding of many specific sub-domains that influence the decision-making process, coupled with the experience that allows for quick and decisive action based on such information (Nonaka & Takeuchi, 1995).

An additional recent awareness is that knowledge management via knowledge capture and knowledge repositories is only a part of the solution to workforce problems.

> If an organization could capture the knowledge embedded in clever people's minds, all it would need is a better knowledge-management system. The failure of such systems to capture tacit knowledge is one of the greatest disappointments of knowledge-management initiatives to date.
>
> (Goffee & Jones, 2007, p. 1)

What is needed are new approaches to knowledge training; in particular, a method for accelerating the achievement of high levels of proficiency. Recognition of this need is illustrated by the many recent

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books that present methods for training an expert business workforce (e.g., Clark, 2008; Goldstein & Ford, 2002; Kraiger, 2002; Quiñones & Ehrenstein, 1997).

The Air Force Weather Agency has launched a program to train "Forecast Ready" forecasters possessing high-level knowledge beyond intermediate skill levels. Such forecasters would be capable of using computer models and remote sensing tools. They are able to "explain the reasoning behind the forecast" (McNulty, 2005, p. 5). To make it possible for training to accelerate learning in this sense, great reliance will be placed on mechanisms of distance learning (Pagitt, 2005). "The 7th Weather Squadron is moving at lightning speed towards a new training initiative … a premier, just-in-time combat field skills training course…" (7 th Weather Squadron, 2005, p. 16).

There are domains of expertise and specialization within the military that are especially strategic and therefore important from a workforce and training perspective, and to which we would ideally be able to apply methods of acceleration. An example domain is maintenance of strategic nuclear and non-nuclear strike systems. Although this domain is not a specific focus of the present volume, it does serve to highlight some issues.

Future needs for specialized skill sets required in the domain of strategic strike capabilities have been the subject of extensive study (e.g., Defense Science Board, 2006). Because of this domain's importance, and some sense of urgency on the part of the Department of Defense, forays into research on innovations in training would not be immediately helpful and therefore not prudent. On the other hand, the recommendations of the Defense Science Board speak directly to the motivation for the study of accelerated learning, including the imminent problem of a retiring generation of engineers and the concomitant loss of organizational knowledge and skill.

Despite the fact that both the Navy and Air Force have programs designed to maintain nuclear strike capabilities, the DSB has expressed concerns about: (1) the lack of knowledge management processes implemented across all of the pertinent organizations, to identify, track and retain critical engineering skills, (2) the challenge of attracting the best students to the pertinent science and engineering disciplines, (3) the need for high levels of proficiency in order to cope with unanticipated failures requiring analysis and redesign, and (4) the need for a new generation trained for adaptation to new concepts and emerging technologies. A main finding of the Defense Science board report on "future strike skills" is the perceived dearth of expertise. "In addition, there is the assessment that current Human Capital Management Systems are insufficient for identifying, tracking and

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managing critical skills" (Defense Science Board, 2006, p. 5). These are the kinds of challenges to which accelerated learning should be applicable.

Technology Issues

A number of recent research and development programs established across the Department of Defense have called for more automation, in an effort to achieve a number of important goals, such as reduced manning of work systems, greater efficiency and effectiveness, and reduced mental workload. The increased complexity of systems causes errors and poor performance. Therefore, the argument goes, we add more automation to make operations simpler, more easily trained, and trainable to lower levels of expertise. We need to be able to use automation to eliminate the need for human supervisors in simulator-based training. And so forth. However, all our lessons learned in cognitive systems engineering and complexity theory imply that more automation may result in simplifications, but they will hide deeper complexity, and at those moments where resilience and high-performance are needed, there will have to be *greater* operator expertise.

In the February 2011 issue of *The Armed Forces Journal*, engineering psychologist John K. Hawley of the Army Research Laboratory discussed the impacts of technological complexity on recent Army operations. His summary of the recommendations of an ARL research team concerning training underscore our motivation for an analysis of accelerated expertise, and highlight a number of the themes that we expand upon in this book.

Hawley begins with a summary of an analysis of fratricide incidents:

> The first contributing factor, undisciplined automation, is defined as the automation of functions by designers and subsequent implementation by users without due regard for the downstream consequences for human performance… Automation bias is defined as unwarranted over-reliance on automation. It has been demonstrated to result in monitoring failures (vigilance problems) and accompanying decision biases usually involving unwarranted and uncritical trust in automation. In essence, control responsibility is ceded to the machine … (p. 1).

But, Hawley continues, this was not a blame game: The warfighters "did what they had been trained to do." The ARL team found that the

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extensive use of automation does not eliminate the need for operator expertise. Warfighters need to have:

> … the technical potential for adequate situation awareness and the expertise to understand the significance of the information available to them. Situation awareness, the key to effective control, involves far more than a simple display of icons on a screen (p. 1).

The ARL research team referred to expertise in the sense of proficiency beyond rote skill; that is, critical thinking and tactical reasoning based on a rich knowledge base. Developing such expertise "takes job-focused training, appropriate on-the-job experiences, mentoring by expert job performers, and, above all, time." Hawley refers to the concept of deliberate practice, arguing that:

> More than 50 years of training research across the DoD has shown that instructional design issues often trump issues pertaining to training equipment and simulator fidelity … Technology-intensive systems require considerable operator and crew expertise for effective use. Research indicates that developing these levels of expertise requires several years of full-time effort just to reach the journeyman level (p. 1).

Finally, Hawley points to organizational issues:

> In spite of the best intentions with respect to training and job preparation, the Army's formal personnel system makes it difficult to keep operators and crews in one position long enough to reach necessary levels of on-the-job competence. Unsupportive personnel practices can undo the best-laid training plans and practices.

Hawley concludes by advocating "expertise-focused training" and echoing a core principle in Human-Centered Computing: "Technology can amplify human expertise, but not substitute for it." This expresses another of the themes that we explore in this book.

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Accelerated Learning and Its Challenges

> Surprisingly, just a handful of researchers have examined the nature of activities that are specifically responsible for performance improvement, and even fewer have translated the methods used and strategies acquired during such activities into meaningful training programs.
>
> (Ward et al., 2008, p. 130)

A History for Accelerated Learning

In Chapter 1 we motivated the idea of trying to rapidize training and accelerate the achievement of high levels of proficiency. A first step is to reference the pertinent literatures of the psychology of learning, the sciences of education and the sciences of training.

The literatures that pertain to accelerated learning are diverse and expansive. Educators have always focused on improving education. A separate discourse would have to span Socrates to Edward Thorndike (1910) and John Dewey (1933, 1938). But in the writings of these individuals, and innumerable others, we can find notions that are echoed today in such approaches as action learning, constructive learning, experience-based learning, case-based learning, demonstration-based training, story-based learning, problem-based learning, and others (see, for example, Kolb, 1984; Revans, 1980; Vasidas & Glass, 2002).

Trainers have always been motivated to improve training, to accomplish more with less and in less time. This is true in all training application domains, ranging from military training (e.g., Hawley, 2011; Hays & Singer, 1989; Schatz et al., 2011; Seidel, Perencevich,

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& Kett, 2004) to corporate or business management training (e.g., Liu, Gao, & Liu, 2011; Moon et al., 2005; Spenser & Spencer, 1993). Rapidization is explicitly the focus of many books on training, witnessed in such titles as *The ten-minute trainer: 150 ways to teach it quick and make it stick*! (Bowman, 2005).

Scores of research articles that are potentially if not indirectly pertinent to concepts of accelerated learning appear in a staggering variety of journals, such as the broadly focused journal *Training* and a huge variety of discipline-focused journals such as *Applied Cognitive Psychology, The Journal of Curriculum Studies, Open Learning, Instructional Design, The Journal of Interactive Media in Education, Computers and Education, The Journal of Workplace Learning, The Journal of Learning Sciences* and dozens of others that emerged in affiliation with one or another specialization, sub-discipline, or community of practice. The literature of research and methods for instructional design is of a scope well beyond the reach of any single book or review. The interested reader is referred to Carliner (2003), Gordon (1994), Lawson (2008), McLean (2010), Schwarz et al. (2005), Seidel, Perencevich, & Kett (2004), Smith & Ragan (2004), Vickers (2007), and Welch (2011). Rapidization is explicitly the focus of a book on how to teach people to conduct instructional design rapidly (Piskirch, 2006).

Numerous edited and authored volumes cover basic concepts and issues of training design, such as the design of practice (massed, spaced, focused, variable, etc.), design of feedback (process, outcome, immediate, delayed, etc.), levels of learning (from rote memorization to meaningful learning), perceptual-motor skill learning versus the learning of "declarative" knowledge, cognitive training, team training, lifelong learning, self-directed learning, distance learning, e-learning, and so forth. The interested reader is referred to Aldrich (2003), Cannon-Bowers & Salas (1998), Farmer et al. (1999), Fiore & Salas (2011), Furjanic & Trotman, (2000), Glaser (1962), Hancock et al. (2008), Hays & Singer (1989), Healy & Bourne (2012), Hertel (2002), Hunt (1997), Jonassen, Tessmer, & Hannum (1999), McCormik & Paechter (1999), Patrick (1992), and Quiñones & Ehrenstein (1997). Simulation-based training receives particular attention in Chapter 14 of this book.

Many studies and concepts discussed in the books and journals cited above (and many other sources as well) do pertain to notions of accelerated learning—such as transfer, retention and the idea of cognitive skills training. A recent monograph by Dunlosky et al. (2013) reviews a number of techniques for improving learning in the context of the educational system (i.e., secondary school through

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undergraduate levels). Example methods are self-explanation, highlighting, and mnemonic learning and deliberate practice. Some of these sorts of methods receive mention in this book. However, the breadth and scope of potentially pertinent work in the learning and training sciences means that we must focus on research and ideas that seem to *directly* pertain to concepts of accelerated learning to high levels of proficiency in professional domains.

In the 1980s, researchers at the Learning, Research and Development Center of the University of Pittsburgh published seminal studies looking at novices versus experts (e.g., Chi, Feltovich, & Glaser, 1981; Chi, Glaser, & Rees, 1982; Glaser, 1987; Glaser et al., 1985). Robert Glaser is widely regarded as a founding father of modern expertise studies.

Writing in the journal *Human Factors* in 1985, Walter Schneider argued that experts are qualitatively different from novices and that it takes long hard work to achieve expertise. He enumerated a number of issues of training (e.g., part-task to whole-task training, the role of motivation, etc.). Most importantly for our purposes, he argued traditional training programs are inappropriate for training “high-level skills” such as piloting and air traffic control. Training to high levels must acknowledge that there will be heterogeneous rates of skill improvement, and that the measurement of performance accuracy alone will not be sufficient. Rather, the instructor has to dig down into the learner’s strategies.

A 1989 chapter by Alan Collins, John S. Brown and Susan Newman was titled “Cognitive Apprenticeship.” It appeared in an edited volume that was in honor of Robert Glaser. Collins et al. referred to the proficiency scale of the traditional craft guilds, noting that instruction at an intermediate level (i.e., apprentice level) has requirements different from those at lower levels.

The concept of facilitating the achievement of high levels of proficiency was discussed in a 1991 Report of the Committee on Techniques for the Enhancement of Human Performance (formed by the Commission on Behavioral and Social Sciences and Education of the National Research Council of the National Academy of Science) (Druckman & Bjork, 1991). The report discussed ways for advancing performance measurement, and referred to the core concepts of transfer, retention, etc. But this report is distinguished from many previous works on training given its reliance on the Collins et al. notion of cognitive apprenticeship, the idea of facilitating the achievement of high levels of proficiency and expertise, and the need to focus on “real-world contexts” (p. 12). The report by Daniel Druckman and Robert Bjork referred to “modeling expertise,” by

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which they meant that training should involve activities of the sort one would expect of an apprentice; that is, learning in context by seeing the master at work. The report emphasized the need to understand how experts reason and what experts know.

We see in these works a clear recognition of notions of pushing training and instruction to high levels of proficiency. It is these sorts of concepts that are referenced in this book.

What this book contributes that is new is a perspective and methodology based primarily on ideas stemming from research in Naturalistic Decision Making (Klein, 1997; Klein & Zsambok, 1995), Macrocognition (Patterson & Miller, 2010; Schraagen et al., 2008), Human-Centered Computing (Hoffman, 2012), Cognitive Systems Engineering (Hollnagel & Woods, 1983, 2005), Cognitive Task Analysis (Clark & Estes, 1998; Clark et al., 2008; Crandall, Klein, & Hoffman, 2006; Feltovich, Ford, & Hoffman, 1997; Hoffman & Militello, 2008; Hollnagel, 2003; Jenkins et al., 2009; Lukas & Albert, 1993), and the field of Expertise Studies as a whole (Ericsson, 2009a; Ericsson, Charness, Feltovich, & Hoffman, 2006; Hoffman, 2007; Hoffman, Ford, & Coffey, 2000; and Schön, 1987). We rely especially on the idea of "accelerated expertise," which emerged in the activities of the Florida Alliance for the Study of Expertise (FASE, 2004; Hoffman, 2002; Hoffman et al., 2009).

Origins of the Concept of Accelerated Learning

The phrase "accelerated learning" originated as the popularization of some scientific concepts. As far as we can tell, the phrase was first used in 1965 as the title of a book by Colin Rose. The book subsequently underwent updates and revisions. The 1984 version, the earliest we could find, began with some discussion at the level of introductory psychology about the nervous system and the wonders of the brain. While manifestly a selfimprovement book, chapters also address how parents and teachers should teach young children, acknowledging some shortfalls in educational systems. Lending some academic credibility, the book refers to models of memory (i.e., short term and long term), primacy and recency effects, the Ebbinghaus experiments, and research on memory encoding by experimental psychologists such as Endel Tulving, and it presents capsule views of a number of projects conducted in school settings. The book presents many bold claims, i.e., anyone can "build a photographic memory," or "learn a new language in 12 days" (at a rate of 1200 new words per day), or "boost" their IQ. The so-called breakthrough in accelerated learning that Rose presents is an amalgamation of mnemonic memory

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aids, mental imagery, listening to baroque music while learning, relaxation, speed reading, and something called suggestology.

The popularization of the phrase continues today: There is a website that promotes “Seven principles of accelerated learning” [http://www.discoverylearning.co.uk/principles/index.html]. This appears to be a course that is built upon some generalizations about memory and the brain.

These sources are not talking about the sort of accelerated learning to which we refer. Nor do we refer to what might be called “relative acceleration.” Improvement in training can often be achieved by improving methods that are clearly lacking in structure or effectiveness. For instance, many organizations proclaim the value of “on-the-job” training (Derouin, Parrish, & Salas, 2005), but have no structured focus on learning, inadequate plans and procedures, and inadequate management or organizational support (Stanard et al., 2002). Acceleration in the sense of improving deficient training is not the focus of this volume.

The first scholastic reference we have found to the notion of accelerated learning is a paper by Carlson (1990) in reference to expertise in the mental health care industry. Carlson’s paper was a proposal, based on the finding of great variation in the effectiveness of mental health services (for depression, alcoholism, etc) across counselors, health facilities, geographical regions, etc. Carlson invoked the Dreyfus and Dreyfus (1986) stages in the development of expertise (see their Table 3.3) arguing that health care workers needed to be trained beyond the use of fixed procedures and rules, up to the stage where reasoning is context-sensitive. Carlson proposed that this situation could be improved if health care analysis were based not on patient throughput, but on the identification of genuine expertise with regard to patient care. Carlson proposed an attempt to instill that expertise through feedback-based training utilizing scenarios created through consultation with highly experienced clinicians.

A recent project conducted in the European Union attempted to develop an e-learning methodology for “accelerated learning” for managers of small businesses (see Moon et al., 2005). This project was motivated by the finding of a 2004 EU commission that small businesses represented 98 percent of all businesses in the EU, but that less than 10 percent of the workforce had taken any management training of certifiable quality. Thus, a 20-hour e-learning curriculum was developed, instituted and evaluated. While related in spirit to notions we discuss in this book, the focus of the EU work was on what we would call rapidized training to apprentice or junior journeyman levels, and not on accelerated learning as we would define it; that is,

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of the training) or even improving retention—and those methods that lead to faster acquisition typically result in poorer retention (e.g., Shea & Morgan, 1979), especially when the lag between acquisition and retention is extended (see Cepeda et al., 2008).

Challenge 2: Accelerated Learning in the Sense of Accelerated Proficiency

The most succinct way of saying this is: "Can we turn an apprentice into an expert in less than ten years?" Accelerated learning in this sense refers not only to the idea of hastening the achievement of a minimum level proficiency; it reaches across the proficiency scale to the question of how to accelerate the achievement of expertise, and whether that is even possible. It is widely recognized that many individuals and teams must be trained to high levels of proficiency, even to the expert level, because of the need for operations that rely on cognitive work and require robust, resilient and adaptive response.

- Robustness is the ability to maintain effectiveness across a range of tasks, situations, and conditions.
- Resilience is the ability to recover from a destabilizing perturbation in the work as it attempts to reach its primary goals.
- Adaptivity is the ability to employ multiple ways to succeed and the capacity to move seamlessly among them.

Fundamental to the achievement of robustness, resilience and adaptivity is the opportunity for practice at problems that stretch current competency (Feltovich et al., 1997). Professionals must acquire knowledge and reasoning skills that pertain to critical domain goals but which must be exercised in differing situations or contexts. Capability *must* transfer in this sense.

Challenge 3: Accelerated Learning in the Sense of Facilitated Retention

Once trained to a high level of proficiency, how can one at least stabilize that level of skill and minimize the amount of decay? The challenge of achieving and maintaining high levels of proficiency is compounded in domains such as the military by such practices as collateral assignment, redeployment (e.g., skill decay on the part of pilots creates a need for expensive re-training), inadequate or ad hoc mentoring, and the drive for just-in-time training.

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> Skill decay is particularly salient and problematic in situations where individuals receive initial training on knowledge and skills that they may not be required to use or exercise for extended periods of time. Reserve personnel in the military, for example, may be provided formal training only once or twice a year. When called up for active duty, however, it is expected that they will need only a limited amount of refresher training, if any, to reacquire any skill that has been lost and subsequently to perform their mission effectively
> (Arthur et al., 1998, p. 58; see also Wisher, Sabol, Hillel, & Kern, 1991)

Challenge 4: Accelerated Learning in the Sense of Rapidized Cognitive Task Analysis

Cognitive task analysis is the study of cognitive work and the modeling of the knowledge and reasoning of domain experts (see Crandall, Klein, & Hoffman, 2006; Hoffman & Militello, 2008; Schraagen et al., 2000). Results from CTA are used in a variety of applications, including the design of intelligent systems. In addition, representations of the knowledge, skills and procedures of domain experts feed into training. Over the past quarter-century, most research on decision-making and other aspects of complex cognitive work has been conducted using some form of CTA. CTA is understood to be labor and time-intensive and requires practiced (and ideally, skilled) practitioners of the craft in order for the investment of time and resources to be worthwhile (see Crandall, Klein, & Hoffman, 2006). Providing valid, useful, actionable findings from CTA requires thoughtful analysis and representation in ways that express meaning and reasoning. Yet, many system development efforts have not relied *enough* on cognitive task analysis, and have instead fallen into the trap of designer-centered design (Hoffman & Elm, 2006; Jenkins et al., 2009). Not only does this preclude the development of a human-centered system, it obviously avoids the actual challenge. But does cognitive task analysis have to take as long as it seems to? Zachary et al. (2007) explored a number of ways we might rapidize cognitive task analysis by looking in detail at factors that affect the time and effort involved, e.g., getting access to genuine experts, developing scenarios, etc.

In this book we do not emphasize this fourth sense of accelerated learning, though it is clearly pertinent to such topics as mentoring and knowledge capture for the creation of training materials, which are topics that we do emphasize in the chapters of this book.

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formed “concrete” (that is, superficial) problem representations. Experts use “abstract” representations that rely on “deep” knowledge; that is, imaginal and conceptual understanding of functional relations and physical principles that relate concepts (e.g., in the case of experts at mechanics, principles such as conservation of energy). Furthermore, experts are better able to gauge the difficulty of problems and know the conditions for the use of particular knowledge and procedures (e.g., if there is acceleration, use Newton’s second law) (Chi et al., 1982).

When experts approach familiar problems, their responses do not tend to be from an analytical or deliberative process as is the case for non-experts (Sternberg & Frensch, 1992). Rather, an organized set of memories drawn from extensive experience forms schemas or mental models (Gentner & Stevens, 1983), which give meaning and structure to familiar and repeatedly encountered problem sets. These schemas provide intuitive, immediate cognitive frameworks to help understand the nature of the problem, derive potential solutions, and anticipate constraints (Reimann & Chi, 1989). This has been called Recognition-Primed Decision Making (Klein, 1989; Oliver & Roos, 2005).

In the “expert performance approach” (Ericsson, 2006) the definition of experts is that they show performance that is reliably superior to that of lesser skilled individuals, on standardized tasks that can be captured under controlled laboratory conditions, and that are highly representative of tasks that would most characterize skill in their domain. This is, as experimental psychologists would like it, almost an operational definition. There is, as there should be, room for contextual adjustment in the definition with regard to the specification of “superior.” One can conceive of superiority in a number of ways: effectiveness, efficiency, or work process quality, all of which are likely to be situationally determined. There is also some wiggle room with regard to tasks that should be considered (most) representative. Presumably, the representative task performance under observation is performance at one or more primary job or task goals (i.e., those aspects of their domain where superiority should be observed in their performance on the job). Those are not always easy to peg down, let alone capture via some single performance measure, nor is it easy to avoid the question of performance at other aspects of the individual’s or team’s job or work domain that are crucial to overall performance. There are also challenges of dealing with domains where the primary tasks are a moving target (Ballas, 2007), and domains where the putative primary task is actually not where the genuine expertise resides (Hoffman, 1992).

Additional features that characterize expertise (see Glaser, 1987;

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		One participant was one of the forecasters for Space Shuttle launches; another was one of the designers of the first meteorological satellites.
Measures of performance at the familiar tasks	Can be used for convergence on scales determined by other methods.	Weather forecasting is again a case in point since records can show for each forecaster the relation between their forecasts and the actual weather. In fact, this is routinely tracked in forecasting offices by the measurement of "forecast skill scores" (see Hoffman, Trafton, Roebler & Mogil, in preparation).
Social Interaction Analysis	Proficiency levels in some group of practitioners or within some community of practice (Mieg, 20001 Stein, 1997).	In a project on knowledge preservation for the electric power utilities (Hoffman & Hanes, 2003), experts at particular jobs (e.g., maintenance and repair of large turbines, monitoring and control of nuclear chemical reactions, etc) were readily identified by plant managers, trainers, and engineers. The individuals identified as experts had been performing their jobs for years and were known among company personnel as "the" person in their specialization: "If there was that kind of problem I'd go to Ted. He's the turbine guy."

A proficiency scale for a given domain should be based on more than one of the four general types of method listed in Table 3.4, and ideally should be based on at least three. This has been referred to as the "three legs of a tripod" (Hoffman, Ford, & Coffey, 2000; Hoffman & Lintern, 2006).

Social Interaction Analysis, the result of which is a sociogram, is perhaps the lesser known of the four kinds of methods. A sociogram, which represents interaction patterns among people (e.g., frequent interactions), is used to study group clustering, communication patterns, and workflows and processes. For Social Interaction Analysis, multiple individuals within an organization or a community of practice are interviewed. Practitioners might be asked, for example,

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In the proficiency scaling in weather forecasting, Hoffman, Coffey and Ford (2000) conducted interviews, sociometric analysis and performance evaluation at a US Navy weather forecasting facility situated at an airfield. By comparison of the forecasts with forecast verification data, it was possible to scale performance. By detailed analysis of personnel records (duty and duty assignments), it was possible to estimate hours spent at forecasting-related activity. Through sociometry and career interviews it was possible to gauge depth and breadth of experience. Depth of experience (number of hours) was compared to breadth of experience, as indicated by the variety of experiences possible— forecasting while at sea, experience in more than one climate, and so on. The expectation was that depth of experience (number of hours) would be verified by breadth (variety) of experience, if only because longer experience affords more opportunities for a greater variety of experiences. By using these combined methods, the researchers converged on a proficiency scale that included levels (expert, journeyman, apprentice) and sub-levels (e.g., junior, senior). Table 3.6 describes the skill factors definitive of each level on the scale.

Table 3.6 Skill factors forming a proficiency scale appropriate to US Navy forecasting

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