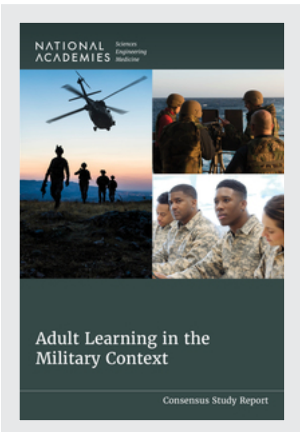

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CONTRIBUTORS

Margaret E. Beier and Emily A. Vargas, Editors; Committee on Adult Learning in the Military Context; Board on Behavioral, Cognitive, and Sensory Sciences; Board on Science Education; Division of Behavioral and Social Sciences and Education; National Academies of Sciences, Engineering, and Medicine

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Adult Learning in the Military Context

Margaret E. Beier, Emily A. Vargas
Editors

Committee on Adult Learning in the Military Context

Board on Behavioral, Cognitive, and Sensory Sciences

Board on Science Education

Division of Behavioral and Social Sciences and Education

Consensus Study Report

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COMMITTEE ON ADULT LEARNING IN THE MILITARY CONTEXT

MARGARET E. BEIER (C*hair*), Rice University
LAURA G. BARRON, U.S. Air Force's Air Education and Training Command
ROBERT A. BJORK, University of California, Los Angeles
SHERNETTE D. DUNN, Air University at Maxwell Air Force Base
ARMANDO X. ESTRADA, Temple University
BENJAMIN S. GOLDBERG, U.S. Army Combat Capability Development Command – Soldier Center
ARTHUR C. GRAESSER, The University of Memphis (emeritus) (service through March 2024)
PATRICK C. KYLLONEN, ETS Research Institute
MICHAEL W. NATALI, Office of Naval Research
AARON R. PHIPPS, West Point
EDUARDO SALAS, Rice University
SAE SCHATZ, Partnership for Peace Consortium
ELIZABETH A. L. STINE-MORROW, University of Illinois
MIKHAIL A. WOLFSON, University of Kentucky

Study Staff

EMILY A. VARGAS, Study Director
SHARON BRITT, Program Coordinator
KATHERINE R. KANE, Research Associate
HEIDI SCHWEINGRUBER, Senior Board/Program Director, Board on Science Education
AMY STEPHENS, Associate Board Director, Board on Science Education
DANIEL J. WEISS, Board Director, Board on Behavioral, Cognitive, and Sensory Sciences

Consultants

JOE ALPER, Independent Science Writer
HEATHER KREIDLER, Fact Checking Consultant

BOARD ON BEHAVIORAL, COGNITIVE, AND SENSORY SCIENCES

Reviewers

This Consensus Study Report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the National Academies of Sciences, Engineering, and Medicine in making each published report as sound as possible and to ensure that it meets the institutional standards for quality, objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We thank the following individuals for their review of this report:

WINFRED ARTHUR, JR., Texas A&M University
HAYLEY F. BENEDICT, Department of Defense, United States Army
SHELLY BLAKE-PLOCH, Yet Analytics
ELIZABETH A. HERON, Air Education and Training Command, United States Air Force
KURT KRAIGER, University of Memphis
FREDERICK L. OSWALD, Rice University
ROSEMARY J. PEREZ, University of Michigan
ALEXANDER A. SMITH, West Point
AVRON SPIRO III, Boston University
JOHN J. STAMPER, Carnegie Mellon University

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations of this report nor did they see the final draft before its release. The review of this report was overseen by **PAUL R. SACKETT,** University of Minnesota, Minneapolis, and **RICHARD N. ASLIN,** Yale University. They were responsible for making certain that an independent examination of this report was carried out in accordance with the standards of the National Academies and that all review comments were carefully considered. Responsibility for the final content rests entirely with the authoring committee and the National Academies.

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- At the first committee meeting, we had the opportunity to talk with Wind and Huntoon from ARI, to get clarity and their perspectives on the statement of task.
- At the second meeting, the committee heard from individuals who provided their expertise during two panels. The first panel was titled, "Military Education and Training: Bridging and Understanding Research and Practice." We are grateful for the following volunteer panelists who served: Sena Garven (The Army University), Jay A. Brimstin (United States Army Maneuver Center of Excellence), Chief Alexander Lamas (Naval Air Warfare Training Systems Division), James Cohn and MSgt. Frank T. Denault (College of Enlisted Military Education & Marine Corps Senior Enlisted Academy). The second panel was titled, "Equity in Military Learning Environments." We are grateful to the following volunteer panelists who served: Aaron Belkin (recorded remarks) (San Francisco State University), Maj. Seung-Min T. Baik (United States Air Force Academy Preparatory School), Morton Ender (United States Military Academy), and MSgt. Summer D. Melillo (United States Air Force).
- At their third committee meeting, the committee heard from individuals who provided their expertise during two panels. The first panel included two individual presentations. Raechel N. Soicher (Massachusetts Institutes of Technology)

presented on adult learning and implementation science and discussed how to bridge basic research and practice. Jamal S. Qaiyyim (United States Air Force) presented on understanding learning contexts and adult learners in the military. The second panel was titled, "Technologies and Interventions to Enhance Adult Military Learning." The committee heard from Andrew Herr (Fount), H. Chad Lane (University of Illinois, Urbana-Champaign), William Swartout (University of Southern California Institute for Creative Technologies), and Tad Brunyé (recorded remarks) (United States Army DEVCOM Soldier Center & Tufts University). We thank all the volunteers who attended the third meeting.

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Contents

Boxes, Figure, and Tables

BOXES

FIGURE

TABLES

Preface

Learning, broadly considered, is an endless preoccupation for students, parents, and educators alike. Questions about how people learn and how to design educational environments to maximize learning have been central to behavioral science since its inception as a science. However, most of this research has considered learning only until late adolescence. Although a focus on younger learners is key to establishing an educated citizenry, a focus on school-aged learners ignores the fact that learning continues across the lifespan. Moreover, the ability to continue to learn and grow is fundamental to remaining employed, employable, engaged, and healthy, particularly in the automated and dynamic landscape of work and life in the 21st century. The importance of lifelong learning is reflected in the shift in coverage from the National Academies' original *How People Learn* consensus report, published 25 years ago, which focused exclusively on childhood and adolescent learning, to the second *How People Learn* consensus study, published in 2018, which incorporated consideration of lifespan learning. Both of these consensus reports influenced the current report heavily and are worth a read.

The current study, *Adult Learning in the Military Context*, narrows the focus to learning for adults in the military context. The U.S. Army Research Institute for the Behavioral and Social Sciences commissioned this consensus report to gather, review, and discuss literature on adult learning in the military context. Reflective of its charge, the committee comprised an impressive group of academics and military members who study learning within and outside of military contexts. As a researcher studying lifelong learning, I was excited about a narrower focus that would highlight the learning landscape for adults, which is complicated by the diversity of experiences, knowledge, skills, and attitudes that adults bring to the learning context. What I did not consider at the beginning of the project was how the military prioritizes learning, how many people learn within military contexts, and how rich and varied the military context is with respect to learning.

As you will read in the report, military learners' experiences are similar to those in civilian contexts in many ways. Military members bring an array of individual differences in abilities, motivation, interests, and experiences to the learning process. They thrive when learning environments are well designed and adapted to their skill and knowledge levels, and they may struggle with learning when they experience underrepresentation and lack of belonging. Similar to other organizations, the military is grappling with the ways in which technology is affecting the work they do, the way they train people to do that work, and the learning opportunities available to military learners, which are increasing in number, if not in quality. In other ways, however, military learners—who comprise both military members and civilians—operate within a relatively well-defined system with an established set of values and cultural norms that can serve to facilitate or impede learning. Moreover, military learners operate within incredibly volatile, complex, and unpredictable environments, which raise the stakes for learning skills that will help them survive.

The committee dove into the research literature on adult learning and adjacent topics and developed this report, its conclusions and recommendations, and a research agenda. We hope that our final product will be of value to the sponsor and more broadly useful to those studying adult learning within and outside military contexts and to military and adult learners themselves. Furthermore, we hope that the recommendations herein can be implemented effectively. To this end, the committee highlighted the need for a systematic approach to training needs assessment in the military context. Here I reiterate that this approach should include consideration of broader contextual barriers and facilitators, such as resources allocated, that may impact the adoption of the committee's recommendations. After all, even well-designed learning interventions will be rendered ineffective if the systems in which they are implemented are not supportive of them.

I am thankful to have had the opportunity to work on this report with an amazingly talented committee. I was impressed with the care and thoughtfulness with which they undertook the task and their mastery of their respective fields. I learned a great deal in the process of developing this report, and as a student of lifelong learning myself, I know that learning is, after all, the goal.

Margaret Beier, *Chair*
Committee on Adult Learning in the Military Context

Acronyms and Abbreviations

AFQT	Armed Forces Qualification Test
AI	artificial intelligence
ARI	Army Research Institute
ASVAB	Armed Services Vocational Aptitude Battery
BBCSS	Board on Behavioral, Cognitive, and Sensory Sciences
BOSE	Board on Science Education
DoD	Department of Defense
GAO	Government Accountability Office
HPL1	*How People Learn* 1
HPL2	*How People Learn* 2
IRT	Item Response Theory
MOS	Military Occupational Specialty
National Academies	The National Academies of Sciences, Engineering, and Medicine
OER	Open Educational Resources
OODA	Observe, Orient, Decide, Act
PME	Professional Military Education
ROTC	Reserve Officers' Training Corps
STEM	science, education, engineering, and mathematics

Summary

The United States military is essential to national security, and its activities have significant implications around the globe. The Department of Defense (DoD) is the nation's largest employer, and though not always appreciated, it is one of the largest providers of training and development for adult learners. Throughout history, learning has been a key priority for the military, and continuous growth and development of military members ensures the ability of the United States to remain innovative and competitive over adversaries in the face of an unpredictable future. Moreover, continuous growth and development are paramount given the ever-changing and complex operational landscape within which the military operates, including increasingly uncertain, volatile, and chaotic environments around the world—on land, at sea, in the air, in cyberspace, and in outer space.

Continuous learning in the military has never been more important than it is today. From the communication skills needed to work effectively with team members and foreign allies to operating complex technology worth millions of dollars, military members need to acquire a wider breadth of competencies, retain them over the course of their careers, and be ready to respond and use those competencies at the right time and place. Success in learning—and the ability to retain and transfer what is learned to military missions—is inextricably linked with operational success and the success of our nation.

Given the essential role of learning in the military, the Board on Behavioral, Cognitive, and Sensory Sciences and the Board on Science Education of the National Academies of Sciences, Engineering, and Medicine convened an expert committee charged with examining the adult learner within the military context. At first glance, the learning and developmental pathways within the military appear to be straightforward and aligned with the hierarchy of titles provided to military members upon promotion. Within these pathways, which follow a continuum from tactical to strategic, military members are expected to learn a range of skills, knowledge, behaviors, attitudes, and interpersonal competencies—such as 21st-century skills—essential for their job and key to fitting into the military culture. The military learner landscape expands beyond uniformed members to include DoD civilians, whose learning pathways are inconsistent and unstructured compared to those of their enlisted and officer counterparts.

Over the course of its research and deliberations, the committee found that the military learning landscape is complex, multifaceted, and diverse within and across the Services. Core values and cultural characteristics of the military, such as power distance, respect, hierarchy, collectivism—including teamwork and selfless service—and military policies, such as service commitment periods and up-or-out policies, may set limits on how much individual autonomy a given learner can have in practice, which can impede motivation for learning. Mission criticality is the central determinant of military assignments, and key to a military member's career trajectory and the knowledge and skills they will need to learn. Military branches also rely on standardized assessments of vocational interests to place military members into careers, thus setting them on a learning and career trajectory. However, the use and quality of these assessments may vary. While many learners enjoy learning for its own sake, supporting the vocational choices of military members and clarifying how skills acquired in military contexts can transfer to civilian jobs after service will enhance motivation for career-related learning and development. Currently, the transferability of the skills learned in military environments may not be clear to military members. DoD civilians would benefit from augmented opportunities, incentives, and enterprise-wide governance methods for supporting learning and development. These efforts can be better organized and align learning opportunities, mission needs, and professional development.

Military learners represent a heterogeneous population and vary in their age, experience, knowledge, and competencies. Fortunately, people retain the capacity to grow and change throughout the lifespan, with younger ages characterized by adaptability, high levels of fluid abilities—which include control, isolating abstract patterns, problem-solving in novel situations, and processing speed—and efforts to establish a sense of purpose. As people develop into mid-life, they accumulate knowledge and competencies that are significant strengths in their own right and can compensate for subtle declines in fluid abilities. Adult development is also typically associated with a shift from achievement to socioemotional goals, a trend that begins to emerge in middle-age. Recent changes in military policy have increased the maximum age for enlistment and increased the number of years that enlisted members may serve. In light of these policy changes (and the absence of mandatory retirement for most DoD civilians), it is increasingly important to take an adult lifespan view of military learners. These individuals can continue to grow and develop though what they want to study and how they need to study may change throughout their careers. An important consequence to the profile of learners through the lifespan is that the wide range of adult learners' knowledge, competencies, and experiences makes them a diverse group. This is where well-designed, technology-enabled learning that can adapt to the unique needs of adult learners can play an important role.

While military learning environments are as diverse as those in non-military contexts—from formal training in the classroom to informal learning on one's own—the tenets of effective instruction remain the same. Introducing desirable difficulties and active learning environments—those that require a learner to construct their own understanding of the to-be-learned content—will lead to better learning. Learners will also benefit from learning environments that are personalized and provide the appropriate level of learner autonomy, given their skill level. Permitting appropriate learner autonomy is not at odds with the collectivist nature of the military but, rather, it helps foster individuals' motivation and self-development in ways that are consistent with the military's needs in developing a strong workforce. Both personalized learning and learner autonomy are increasingly available with technology-enabled learning. However, the committee feels it important to note that personalizing learning environments for individual learners is not the same as categorizing learners based on learning style, which has not been supported in the scientific literature. An increasing amount of learning within, and outside of, the military happens outside formal training experiences, highlighting the importance of motivational processes such as self-regulation during learning. Motivation for learning is enhanced when learners feel supported by their institutions, superiors, and peers to engage in learning and feel a sense of belonging and psychological safety to make—and admit—mistakes.

Regarding more formal training environments, the committee found that systematic needs assessment—a best practice for training design, development, implementation, and evaluation—may be particularly useful for Professional Military Education but is somewhat unevenly implemented in the military context. Moreover, when military members enter the classroom for training, the committee found, a lack of instructor training and support may undermine learning in formal contexts. Regardless of the formal nature of the learning environment, research conducted outside the military suggests that similarity between instructor or mentor and learner, particularly in terms of factors that are malleable such as interests, can affect learning outcomes.

Technological advances continue to shape how people learn. The science of technology-enabled learning is mature in several ways. For example, well-established principles of multimedia instructional design, experiential learning through simulations, adaptive instruction, and technology-supported self-directed learning can greatly enhance learning outcomes—and at scale. Emerging technologies, such as generative artificial intelligence, offer more exciting possibilities. However, despite its promise, technology-enabled learning is often limited in practice because military organizations may implement it without the necessary human and organizational considerations, such as usability, sufficient faculty training, and coherent pedagogical strategies.

Another challenge for technology-enabled learning is embracing a systems approach, which considers the diversity of learning and operational experiences holistically—rather than addressing each as a standalone experience. For technologies, this means considering a Digital Learning Ecosystem approach in which different learning technologies are connected together via interoperable standards, interfaces, and data. For the corresponding people and processes, it means considering learning engineering methods and practices.

The committee also discussed one essential difference between the military and most learning contexts: the dangerous and high-stakes conditions of warfare. Although the end goal of survival may be uncomfortable to discuss, military members are expected to support this goal either directly or indirectly. In some instances, this may involve killing others. Additionally, military members are often expected to change jobs, relocate frequently, and they will be expected to face routine stressors, including balancing family and job demands, meeting professional responsibilities, as well as undergoing routine assessment and evaluations as continuous learners. As a rule, such environments will be stressful. Stress can facilitate or impede learning, depending on how the learner interprets the stress. Chronic stress, which may be more prevalent for some military members, will almost certainly impede one's ability to learn. Within military contexts, little is known about the effects of chronic stress on learning outcomes, and additional research is needed. Less obvious, perhaps, but also affecting learning is the stress in learning environments introduced by inequalities associated with diversity, equity, and inclusion. Although research in a military context is limited, it is well established that a reduced sense of belonging resulting from negative interpersonal treatment can reduce motivation and undermine learning. Surface-level factors, which generally include non-malleable characteristics such as gender and race, can also create barriers to learning, particularly when learners are underrepresented in the learning environment. The military's demographic composition may induce these learning barriers, depending on the branch and whether a military member is an officer or enlisted.

Given these complexities, assessing learning in military contexts is ever more challenging. Although a burgeoning area of research, there are limited validated assessments of the types of competencies important in military contexts, such as adaptability, creativity, and communication. Current assessments in military and civilian contexts are also plagued by biases and difficulties in design, such as one-time, post-test-only assessments. More powerful assessments are needed, as are more thoughtful approaches for understanding the effect of bias and validity threats on assessing learning intervention effectiveness. Despite these challenges, technology promises to affect assessment in the same way that it changes how people learn. For instance, technology-enabled learning can provide formative feedback as a learner progresses through learning content. Technology will also inevitably aid in collecting learning data, which can be used to develop a comprehensive Digital Learning Ecosystem that could significantly enhance the availability of self-directed and self-regulated learning within the military. Such a system could connect learning experiences across a career, deliver the right learning experiences where and when needed, and support data-enabled systems-wide improvements.

In summary, the military provides an interesting context for examining adult learning. The committee provides an array of recommendations aligned with its overall findings, presented below.

RECOMMENDATIONS

Recommendation 1: To the extent feasible and appropriate, Department of Defense organizations should allow military members to exercise disciplined autonomy over their career pathways and individual learning trajectories:

- **Leaders of all Service branches should continue encouraging and rewarding military members for being proactive in attending to their own self-**

development by, for example, seeking informal learning opportunities and mentorship. In addition, the Department of Defense should formalize policies where needed to provide resources such as time, in accordance with mission constraints, to allow for these activities.

- **To advance military readiness, the U.S. military should continue training leaders to foster a culture that encourages and promotes proactive self-development. This may include strategies on effectively communicating learning data to individual learners.**
- **Training Commands and Professional Military Education institutions should continue to identify opportunities for military members to exercise individual autonomy in learning, for example seeking elective courses and mentorship. Opportunities may vary based on factors such as military occupational specialty.**
- **The Army Office of the Deputy Chief of Staff for Personnel should implement validated vocational interest tools to gauge military recruits' interests and leverage recruits' sense of autonomy by better aligning occupational placement to vocational interests, in accordance with mission constraints. For example, the Army could implement the Adaptive Vocational Interest Diagnostic assessment that has been evaluated in Army samples, or develop new vocational interest assessments that more closely parallel those adopted by the Navy and Air Force.**

Recommendation 2: The Defense Human Resources Activity, in coordination with the Service personnel offices, should augment opportunities, incentives, and enterprise-wide governance methods for supporting Department of Defense civilian learning and development. This work should better organize and make discoverable these opportunities and align them to mission needs and to professional development opportunities.

Recommendation 3: Service training and education commands, as well as Professional Military Education institutional leaders, such as commandants, should conduct a systematic analysis to identify gaps in existing military-to-civilian transition

services focused on the extent to which competencies developed in the military translate into the civilian labor market. The analysis should also identify areas of overlap in which the military can integrate civilian-based education and certification into its own curriculum.

- **Findings from the analysis described above should be used to develop new approaches to improve support and services for this transition.**

Recommendation 4: Service-specific and Joint Professional Military Education institutions, in coordination with the Military Education Coordination Council as applicable, should identify gaps where systematic needs assessments are not being fully and regularly conducted to guide the design, implementation, and evaluation of educational programs and to better align learning with mission requirements to maximize effectiveness. These assessments should include the consideration of the broader contextual factors and facilitators that may impact implementation.

- **Needs assessments should establish learning activity requirements aligned to course curriculums and objectives. An emphasis should be placed on identifying active and experiential learning through continuous assessment needs to drive optimal outcomes and the transfer of learned competencies outside of the classroom. Findings from needs assessments should be used to modify existing practices when and where necessary.**
- **Develop new measures of competencies, leveraging rigorously developed competency frameworks such as the Army Talent Attribute Framework. Engage and coordinate with Professional Military Education institutions in standard-setting exercises to establish better defined levels of proficiency for each competency across the Department of Defense.**

Recommendation 5: Service training and education commands, as well as Professional Military Education institutional leaders, such as service academy commandants, should provide more robust supports for military learning facilitators, including instructors and instructional designers, to minimize barriers, leverage their strengths, and improve the effectiveness of learning by taking the following actions:

- **To improve military instructor quality, and in accordance with mission constraints, identify suitable opportunities to increase instructor tenures and properly reward instructors.**
- **Provide more robust training and professional development about learning principles and best practices in education for all learning facilitators prior to teaching, training, or instructional design assignments. Provide ongoing support and mentorship for learning facilitators during and after they receive this training.**
- **Provide more robust training and support for instructors and other instructional staff on interpersonal skills and socioemotional competencies to maximize their potential as mentors for military learners.**
- **Build a more robust credentialing system to establish a systematic approach for collecting and verifying data regarding learning and development of instructors.**

Recommendation 6: Service training and education commands as well as Professional Military Education institutional leaders, such as commandants, should identify which considerations of stressors need to be incorporated into training and education that meet varied contextual needs to support mission success. This may include, for example, teaching learners to frame stressors as challenges and not threats.

Recommendation 7: Department of Defense research institutions, potentially via a collaboration between the Human Systems Community of Interest and the Office of People Analytics, should conduct a systematic analysis of the prevalence and effect of numeric diversity and interpersonal factors of equity and inclusion, specifically in the military learning context, and examine their effects on learning effectiveness for military learners. This should be done in accordance with privacy-related legal considerations.

- **Department of Defense training and education institutions should use findings from the analysis described above to inform new training and professional development strategies for their instructors and other instructional staff. This**

may include, for example, promoting psychological safety and a sense of belonging in learning contexts by reflecting on commonalities and shared experiences with their students.

Recommendation 8: Researchers and developers involved with technology-enabled learning should incorporate the best practices and systematic approaches of Learning Engineering and the Digital Learning Ecosystem concept early in a product's lifecycle, as early as the Applied Research phase (i.e., U.S. Department of Defense "Budget Activity 6.2").

- **Establish repeatable Learning Experience Design principles to support usability and user-experience design and develop repeatable ways to implement these human-centered design methods reliably and efficiently.**
- **Explore and integrate modern data collection methods, such as automated and noninvasive instrumentation, multimodal data fusion methods, and inferential analytics to enable data-informed optimization of learning experience.**
- **Define requirements for analytics (in the context of learning) early, including instrumentation for data collection, standards for data interoperability, and plans (informed by learning science) for using the resulting data to drive meaningful outcomes.**
- **Conduct systematic needs assessments to understand the context of use, people, and processes necessary for effective implementation of technology-enabled learning. Procurements of technology-enabled learning components should also be informed by such analyses. This recommendation applies to technologies as standalone devices within the larger military enterprise. Avoid technology acquisitions that are driven by subjective impressions of a solution's innovative nature.**
- **Researchers and developers should consider the realistic context of use and to design holistic solutions—not only building technology innovations but also designing the other components necessary for their applied use in military contexts.**

Recommendation 9: Department of Defense organizational stakeholders overseeing human-systems research, training, education, personnel, and digital systems (e.g., Army Futures, Naval Education and Training Command, Air Education and Training Command, Marine Corps Training Command, Space Training and Readiness Command, and the Chief Digital and Artificial Intelligence Office) should work concurrently toward implementing a Digital Learning Ecosystem. That ecosystem would include intra- and interoperability, data-informed orchestration, and enterprise analytics across the continuum of learning contexts and experiences throughout individuals' careers.

- **Using a Modular Open Systems Approach, collectively develop shared standards (in conjunction with public consensus standards organizations), enterprise software systems, and the standardized components needed for the technical infrastructure of a Digital Learning Ecosystem.**
- **Establish reliable processes for testing new capabilities using the Digital Learning Ecosystem infrastructure, including methods for rapidly plugging in experimental systems and A/B testing.**
- **While maturing the Digital Learning Ecosystem, also iteratively develop, document, and implement corresponding Learning Engineering practices.**
- **Establish processes for managing the digital artifacts required to enable a Digital Learning Ecosystem, such as interoperable learning activity data interfaces with shareable data profiles representing the learning experiences, competency frameworks based on principles of semantic interoperability, interface standards, multimedia components, standardized object metadata formats, and methodologies for representing learning experiences as part of a summative and authoritative record.**
- **Develop common and aligned frameworks of Department of Defense-wide performance proficiency standards for competencies. These frameworks should facilitate interorganizational content alignment and support technology-enabled learning by serving as referenceable metadata.**

Recommendation 10: Professional Military Education institutions, technical training schools, and defense research organizations should provide continued investment in efforts that can support the future of assessment and program evaluation:

- **Invest in the continued promotion of research designs and methodologies to enhance the validity and reliability of evaluation of learning in military contexts, for instance, augmenting support for cooperative research endeavors that aim to maximize representation of learners through novel sampling methods.**
- **Support best practices in assessment including designs that encompass pretest, posttest, random assignment and control groups where permissible, with attention to transfer of learned skills to performance on the job and return on investment. When such approaches are difficult or impossible to implement, explore alternative quasi-experimental designs. Clearly articulate limitations of a design on causal inferences regarding efficacy findings.**
- **Invest in further development of assessments of hard-to-measure competencies.**
- **Label and retain assessment data, whenever possible, to be used for conducting longitudinal analyses, training machine learning models, and other research applications.**

1
Introduction

The U.S. military's role in safeguarding national security is vital, and its actions have far-reaching effects on all aspects of society. As of 2022, the Department of Defense (DoD) had more than 2.1 million military service members (of which 800,000 were National Guard and Reserve forces) and an additional 770,000 civilian employees, making it the largest employer in the country (*Agency Financial Report,* U.S. DoD, 2022a). While not always thought of this way, the military is also one of the largest training and education contexts in the United States (Minnis & Kirchner, 2021). As such, every member goes through some type of training or educational opportunity, and the U.S. military has dedicated many resources and efforts to promoting learning (*The Army Learning Concept for 2030-2040*, U.S. Department of the Army, 2024; Fletcher, 2009; Murray, 2014). Learning is both a priority in the military and is inextricably linked with military success, from that of individual service members to overall national defense capabilities. The people who join the military and become those learners are adults. However, when people are told to imagine a "learner," an image of a child or adolescent may come to mind, and not necessarily an adult in the military. In addition to this common image of who learners are, much empirical research conducted over the past several decades has focused on better understanding how children learn (National Research Council, 2000). Although this younger population frequently represents learners in both imagination and in science, learning is not a process confined to youth but occurs across the lifespan and continues throughout adulthood.

Learning has been defined as the engagement in mental processes that result in the acquisition of new competencies, such as skills, knowledge, and attitudes. Additionally, it incorporates the retention of these competencies over time and the application of them in a needed context (Kraiger & Ford, 2021). A National Academies of Sciences, Engineering, and Medicine (National Academies) consensus report compiled evidence on learning that concluded: "People continue to learn and grow throughout the lifespan, and their choices, motivation, and capacity for self-regulation as well as their circumstances, influence how much and how well they learn and transfer their learning to new situations" (National Academies, 2018, p. 223).

Importantly, adults represent a heterogeneous population and a highly varied group of potential learners. It is necessary to focus on adult learners specifically to better understand learning and account for this complexity. For instance, adults may bring with them a number of experiences and accumulated knowledge from postsecondary education and employment. They may have a working understanding of how to leverage technology to acquire information and learn on-demand and may have established professional resource networks that can supplement their learning over time. Further, adults occupy positions across many sociopolitical and occupational sectors in the United States. An adult's ability to acquire, retain, and perform can have critical implications for not only themselves but society in general, including the military (Beier, 2022).

The current report will recognize and focus on the uniqueness of adult learners. It will describe how motivational and socioemotional factors in adults shape learning; how individual variation in cognitive skills, knowledge, dispositions, and motivation can shape the learning process; how individuals change (or not) throughout the adult lifespan; and how these changes may affect learning.

The National Academies has produced several highly influential reports focused on learning science that are directly relevant to the current report. In 2018, a consensus report titled, *How People Learn II: Learners, Contexts, and Cultures* (HPL2) was published (National Academies, 2018). This report updated a previous National Academies report published almost 20 years earlier, titled, *How People Learn: Brain, Mind, Experience, and School: Expanded Edition* (HPL1) (National Research Council, 2000). In addition to including the most up-to-date science, HPL2 broadened the conceptualization of learning contexts to include other learning environments beyond the formal schoolhouse. The National Academies has also published reports focused on topics of interest related to adult learners and adults more broadly, such as adult literacy (see Box 1-1 for a full list and description of related reports).

In 2014, the National Academies published a consensus report focused exclusively on the military context titled, *The Context of Military Environments: An Agenda for Basic Research on Social and Organizational Factors Relevant to Small Units*. This report presented recommendations for a program of basic research focusing on both social and organizational factors associated with the military context. While the report discussed many contextual features, it was not within its scope to focus on the adult learner or learning. The current report is among the first to intentionally bridge learning science, individual-level factors of learners, technologies, and assessment and tie them to a larger and updated literature on the military context. The current report sits within a relatively unique and specific military context; the Committee on Adult Learning in the Military Context has endeavored to draw on research in military contexts and use military examples throughout. However, the committee draws connections to more general research when needed. Furthermore, the committee believes the picture it paints of the adult learner in the military context can provide more general insights into adult learning and interest an audience beyond the military.

BOX 1-1
Relevant National Academies Reports

The National Academies has published consensus reports that have focused on various aspects of adult learning and military contexts. Listed below are the names and brief descriptions of several key reports that address topics and themes related to the current report. A complete and free version of each report is available at: https://nap.nationalacademies.org/.

Theme 1: Learning Science

- *How People Learn: Brain, Mind, Experience, and School: Expanded Edition* (2000). Published over 20 years ago, HPL1 provides evidence on basic principles of learning science. It includes suggestions for how to apply the science to the classroom.
- *How People Learn II: Learners, Contexts, and Cultures (2018).* This report provides an update to HPL1, focuses on various learning contexts, and examines learning across the lifespan. HPLII takes a multidisciplinary and multi-level approach, integrating work from multiple fields and considering related factors from macro through micro levels.

Theme 2: Adult Populations

- *Improving Adult Literacy Instruction: Options for Practice and Research* (2012a). With more than 90 million U.S. adults lacking adequate literacy, this report synthesizes research on literacy and learning, with the goal of improving instruction.

- *Are Generational Categories Meaningful Distinctions for Workplace Management?* (2020). This report reviews evidence examining if age-related generational categories are significant and if they have implications in the context of the workplace. This includes a proposed line of future research.
- *Understanding the Aging Workforce: Defining a Research Agenda* (2022). This report outlines a research agenda addressing a number of factors, including social and structural factors, in relation to an aging U.S. workforce.
- *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century* (2012b). The "21st century skills" discussed in this report are linked to success in various sectors, such as work and education. The report considers the importance of these skills for youth to meet future challenges as adults.
- *Supporting Students' College Success: The Role of Assessment of Intrapersonal and Interpersonal Competencies*. The report discusses the critical role of intrapersonal and interpersonal competencies in college success, identifying eight key competencies and recommending further research, assessment, and intervention strategies to improve educational attainment in the United States.

Theme 3: Military Contexts

- *The Context of Military Environments: An Agenda for Basic Research on Social and Organizational Factors Relevant to Small Units* (2014). The U.S. Army faces a number of complex challenges related to personnel readiness and mission success. This report presents recommendations for a program of basic research, focusing on both social and organizational factors.

Theme 4: Human Performance

- A foundational three-volume series examined various aspects of human performance and learning that are applicable across a range of applied contexts, including the military. The first publication, *Enhancing Human Performance: Issues, Theories, and Techniques* (1988), was followed by *In the Mind's Eye: Enhancing Human Performance* (1991), and *Learning, Remembering, Believing: Enhancing Human Performance* (1994).

THE MILITARY CONTEXT

Learning is an essential priority in the military. Nested within the DoD, each of the Military Services—Army, Navy, Air Force, Marine Corps, and now Space Force—functions as its own learning organization. This is also true for the other DoD components, including the Joint Staff, combatant commands, and other defense agencies. There have been a number of frameworks, publications, and initiatives spanning the entire U.S. military to provide the necessary resources, instructions, and details to ensure that effective learning can take place (*U.S. Army Learning Concept for Training and Education 2020-2040*, U.S. Department of the Army, 2017; *Training and Education 2030,* U.S. Marine Corps, Department of the Navy, 2023). For instance, the U.S. Army published *The U.S. Army Learning Concept for Training and Education 2020-2040,* which provides an overarching framework describing how it supports and will continue to support learning across numerous programs and processes (U.S. Department of the Army, 2017). In 2024, the Army published *The Army Learning Concept for 2030-2040*, which describes the future of the Army as a learning organization that develops Army civilians and soldiers with the skills they need to succeed (U.S. Department of the Army, 2024). Similarly, the Marine Corps published a doctrine that articulates the philosophy that learning is critical to the profession of arms, and it remains central to the institution and the core of its operations (*MCDP 7*, U.S. Marine Corps, 2020). Although there are some variations across the Services, these efforts often describe learning as an organizational responsibility, partly because success in learning is intertwined with operational success.

What it takes to achieve operational success, however, has become increasingly complex in recent years. Historically, military operations were more straightforward than they are today. In the past, a warfare operation may have included engaging in tactical combat between the U.S. and an adversary on land. Military members would have participated in some type of training or education to be able to perform at the time of the operation. This particular scenario may have required soldiers to learn skills such as firing and fixing a weapon, navigation, and responding to commands to carry out a specific mission. Today, the operational landscape of the military has expanded rapidly and has become increasingly complex (*FM 3-0 Operations,* U.S. Department of the Army, 2022; *National Defense Strategy,* U.S. DoD, 2022b). As this report will discuss, operations increasingly span multiple domains, taking place simultaneously over space, cyber, air, land, and sea. Each of these operations may incorporate greater degrees of ambiguity and chaos, and these operational environments may be extreme and life-threatening (Lampton et al., 2003; Smith & Barrett, 2019; Sullivan-Kwantes et al., 2021; *The U.S. Army in Multi-Domain Operations 2028,* U.S. Army, 2018). Military members may need to leverage advances in rapidly evolving technologies (Toukan et al., 2024; Yonekura et al., 2024), learn a broad range of competencies, and be able to work on distributed teams. Consequently, the military context is becoming increasingly unpredictable and ever-changing, all while the conditions of warfare continue to remain dangerous and high-stakes.

THE MILITARY LEARNER: A STUDY OF ADULTS IN CONTEXT

Focusing on both adult learners *and* the military context raises important questions about context and motivation. Although many working environments are similar between military and civilian contexts, the extreme nature of training to kill, survive, and put one's life on the line is a contextual backdrop that the majority of civilian adult learners may never encounter. To meet the demands of rapidly expanding operational environments, military members may need to become proficient in a wider array of skills, abilities, and knowledge than ever before. Now, in addition to learning how to engage in combat, military members may need to learn how to operate complicated military technology, work on joint military teams, respond to events with a high degree of cultural competency, and make decisions in rapidly evolving and ambiguous situations. Furthermore, military members will need to retain many developed proficiencies over time, and potentially generalize them to new situations over their individual career trajectories. Thus, attending to how people learn best in military contexts includes consideration of the individual and environmental factors that contribute to learning. These environmental factors include the instructors and the technology that support adult learning and how and when learning is assessed and evaluated. Understanding adult learning in the military is critical for maintaining readiness (Congressional Research Service, 2020) and for the United States to remain innovative and competitive compared to its adversaries in the face of an unpredictable future (*TRADOC Pamphlet 525-8-2*, U.S. Department of the Army, 2017). The current report will also incorporate these important considerations.

STUDY APPROACH AND STATEMENT OF TASK

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI), specifically its Basic Research Program, tasked the National Academies with developing a consensus report that would gather, review, and discuss the literature on adult learning in the military context. The statement of task defines the scope of the report to include a range of contextual factors associated with the military context, individual-level factors specific to adult learners with a focus across the lifespan, promising learning technologies and approaches to assessment and evaluation, and a forward-looking research agenda (see Box 1-2 for the full statement of task). The National Academies' Board on Behavioral, Cognitive, and Sensory Sciences, in collaboration with the Board on Science Education, appointed a diverse and well-balanced committee of 13 experts to address the statement of task (see Appendix A for biographical sketches). The Committee on Adult Learning in the Military Context included individuals with expertise in learning sciences, adult development and cognition, military members and practices, technology, personality psychology, economic factors influencing career motivation and professional development in the military, as well as expertise on issues related to diversity, equity, and inclusion.

BOX 1-2
Statement of Task

An ad hoc committee of the National Academies of Sciences, Engineering, and Medicine will gather, review, and discuss the available literature on adult learning with a focus on learning in military environments. The committee will also draw on literature on adult learning in relevant nonmilitary contexts and note the limitations of applicability to the military. When information is limited with respect to adult learning, the committee may draw upon research on children and adolescent learning. The committee will develop recommendations related to supporting learning in the military as well as a research agenda for the Army Research Institute. The committee's work will be guided by the following questions:

1. What are the motivations shaping learning in adults? How do motivations change (or not) throughout the lifespan, and how do these changes impact learning behaviors?

2. How do contextual and equity factors (including but not limited to task/situation; team; organizational; cultural, societal, and life cohort factors) shape the effectiveness of training and of personnel policies and practices? Where is additional research needed?

3. What are the most promising topics related to emerging learning technologies for immediate investment and near-term payoff?

4. What approaches to assessment and evaluation of adult learning and developmental outcomes are most effective? What deficiencies in the current approaches to assessment and evaluation might impede accurate measurement of learning and of developmental outcomes?

5. What, if any, additional research investments should be made to better understand adult learning in the military context and to fully utilize contextual factors in achieving organizational effectiveness?

Study Process

To address the statement of task and prepare this consensus report, the committee met a total of five times from September 2023 to June 2024. In each meeting, the committee collected and reviewed evidence, engaged in deliberations, developed the report, and had the opportunity to bring in evidence and perspectives from outside the committee. For a complete list of names, affiliations, and areas of expertise of all guest speakers, please see the Acknowledgements section. At the first meeting, the committee and the sponsor met in an open, publicly available session with the goal of discussing and seeking clarity on the statement of task. The committee wanted to better understand the intended effect and use of the report by ARI. At the second meeting, the committee heard from two panels of invited speakers in an open-session information gathering workshop. The first panel focused on various forms of education and training that occur in the military context. This panel helped the committee better understand these learning contexts across the career of military members and the commonly used methods of evaluation and assessment. The second panel focused on discussing the various diversity and equity factors that may shape the effectiveness of learning in the military. The committee benefited from the presented materials and the discussions that occurred.

Similar to meeting two, at meeting three the committee heard from two panels of invited speakers in an open-session information-gathering workshop. The first panel covered several key issues related to the statement of task. One speaker on this panel discussed training and education contexts and perspectives on adult learners in the military context. The other speaker discussed adult learning and efforts to bridge basic research to practice. The second panel featured experts who focused exclusively on the topic of emerging learning technologies.

In addition to these workshops, the committee commissioned three papers by outside experts to provide in-depth analyses on select topics to inform the development of the report and aid the committee in fully addressing the statement of task. The first commissioned paper, authored by Janice H. Laurence, discussed the landscape of learning pathways in the military, namely, the general education and training pathways starting from early career and progressing through late career. The second commissioned paper, authored by Jeremy Jamieson, focused on examining stress, a salient factor that emerges across a number of contexts in the military, and its relation to consequences associated with learning in adults. The third commissioned paper focused on a range of emerging learning technologies. Specifically, Gianluca Borghini and Fabio Babiloni summarized the literature reviewing neurological, biological, and physiological interfaces in adult learning within military contexts.

During its fourth meeting, the committee continued discussing the draft of the report and providing evidence to support its conclusions and recommendations. During the fifth and final meeting, the committee reviewed and reached consensus on the draft of the report and the language of the conclusions, recommendations, and research agenda.

The current consensus study represents an important contribution to the literature, but it does not come without limitations. The consensus study process is informed by both budget and time constraints at each step. Therefore, the current report is not intended to be exhaustive, but rather it is designed to be a complete response to the statement of task. Within each step of the process, the staff and the committee made deliberate efforts to maximize the representation of expertise reflected within the scope of the current work. For instance, the committee appointment process was extensive and included a public call for nominations for potential members. Once the committee was formed, its members leveraged the resources available to them to address expertise gaps and bolster the body of evidence in the report. Specifically, the committee scoped the topics of commissioned papers, conducted a wide literature review, and invited guest speakers who represented expertise across various branches, training and education contexts, diversity and equity topics, and learning technologies. As stated previously, panel discussions with outside experts took place in sessions that were available for the public to attend and gain awareness of the information gathered. Finally, it is anticipated that this report will inspire continued future research related to these areas.

Definitions and Terminology

To guide the development of the report, the committee deliberated on terminology. It recognized that there are various terms to describe adults in the military. The committee agreed to use the term "military member" throughout the report when referring to uniformed military members and "DoD civilians" to refer to civilians. In addition, the committee aimed to accurately capture details from specific studies, using their nomenclature and examples where appropriate. The term "military learner" is used when no details are available or the findings are relevant to the broader population.

Central to the statement of task, the committee discussed the definition of *learning*. The committee found that there are small differences in the definition of learning between the Services and the empirical literature. They decided on a definition that bridges the definition used in the literature to the one used in the DoD. As such, the committee defines learning as *the acquisition of new skills, knowledge, and/or attitudes as a result of cognitive and affective engagement with experience, with consequent context-appropriate changes in behavior* (*DoDI 1400.25-V410,* U.S. DoD, 2013; Kraiger & Ford, 2021). The committee distinguishes between the terms *learning* and *performance,* with performance referring to temporary fluctuations that can be observed or measured after learning acquisition (Soderstrom & Bjork, 2015). It is important to note that the military distinguishes between the terms *training* and *education*. Although there are small differences in the definitions of these terms by the Services (see, for example, *MCO 1553.1B*, Commandant of the Marine Corps, 2024), military "training" is generally defined as preparing personnel to perform specific tasks or meet known job performance requirements, while "education" is viewed as broader preparation (e.g., intellectual and character development) for unknown future situations (e.g., see *DoDI 1400.25 V 410*, U.S. DoD, 2021). Some sectors, including the Air Force and DoD, also describe *professional development* as maintaining and improving personnel capacity to complete tasks that are currently part of their duties or that may become part of their duties. Professional development is intended to open up pathways for career advancement within an occupation (e.g., see *DAFI 36-2670*, U.S. Department of Air Force, 2020). The committee uses the terms training, education, and professional development when applicable.

As this report will articulate, there is a broad range of skills, knowledge, behaviors, and attitudes intended to be learned in the military. The committee deliberated on the vast number of terms to characterize what is being learned and acknowledged that there are differences by field and that each term has potential strengths and weaknesses. Although no set of terms was perfect, the committee elected to use the term *competencies*. This definition reflects how the term is generally defined and used in the industrial/organizational psychology literature; that is, a cluster of knowledge, skills, abilities, and other characteristics (Campion et al., 2011; Shippmann et al., 2000), which can yield impactful outcomes on job performance. Under the umbrella of competencies, the committee further distinguished between *soft skills,* to generally refer to interpersonal and intrapersonal skills and attitudes, and *hard skills,* to refer to skills that are more tactical, cognitive, or technical in nature (see Chapter 2 for further discussion and examples). These groupings were based on existing models, including the 21st Century Skills, and competencies identified by the committee in the evidence base (National Research Council, 2012b). Overall, the use of the term *competencies* and the distinctions within them are meant to help improve the readability and understanding of the report. These distinctions, in particular the terms "hard" and "soft," are not meant to imply that some competencies are more valuable than others. All other terms relevant to addressing the questions within the statement of task are defined within the body of the report (see Appendix B for a glossary).

Interpreting and Addressing the Charge

Per the statement of task, the committee was charged with examining how adults learn generally and within the military context. Therefore, when gathering evidence, the committee kept both the adult learner and the military context at the forefront. The committee recognized that there were instances in which the literature focused solely on adult learners or the military context. The statement of task provided direction on which evidence the report could incorporate, stating that the committee could expand on the literature base to incorporate findings from non-adult populations and nonmilitary contexts when necessary. Throughout the report, the committee notes when it incorporates a more general body of literature and any limitations of applicability. Regarding adult learners, the committee adopted a lifespan approach to discuss how changes over time (developmental and career) function as a continuous process. The committee incorporated evidence spanning the entire adult age spectrum (18+) and discussed its findings through this lens.

Further, the committee discussed the report's audience. Because the report was requested by ARI, the committee developed the report in a way that would help maximize ARI's potential implementation. Additionally, the committee recognized the report's applicability to a broader audience and opted to include military personnel across a broad range of U.S. military contexts, as well as researchers and practitioners focused on questions related to adult learning. Thus, this report is inclusive of each of the Services within the DoD—Army, Navy, Air Force, Marine Corps, and Space Force, as well as other DoD components, including the National Guard, and other Reserve components.

In interpreting the second question in the statement of task pertaining to contextual factors, personnel policies, and practices, the committee elected to focus on entities overseen by the DoD. The committee and others have noted that the Coast Guard is overseen by the U.S. Department of Homeland Security during times of peace (*U.S. Coast Guard History,* U.S. Coast Guard, n.d.) and may have some distinct contextual factors not fully considered in the current report. However, the committee believes that the body of evidence included in the report, as well as the conclusions and recommendations, would still be largely applicable to the Coast Guard, and also comparable to some nonmilitary communities. The committee incorporated evidence and examples from various Services and leveraged information based on available information. For instance, the Army is the largest and oldest Service (Arlington National Cemetery, n.d.), and therefore had more evidence for the committee to incorporate, relative to other entities. The Space Force, by contrast, is the smallest and newest Service (established in December 2019); thus, there is less evidence incorporated for this Service.

Some additional notes may be helpful for readers less familiar with the organization of the U.S. military. By law, each of the individual military departments (Department of Army, Department of Navy, and Department of Air Force) is responsible for training its respective military personnel.[1] At the same time, DoD-wide policies often set requirements that Service-specific training and education programs are required to follow. Additionally, many formal and informal learning contexts in the U.S. military are "joint" by design (such that Army personnel

[1] The Department of Navy includes both the Navy and Marine Corps, and the Department of Air Force includes both the Air Force and Space Force. As such, the Marine Corps and Space Force leverage department-wide training and education in some cases; for example, U.S. Air Force Academy cadets may commission as either an Air Force or Space Force officer, and U.S. Naval Academy cadets may commission as either a Navy or Marine Corps officer. See Congressional Research Service (2020).

learn alongside their counterparts from other DoD components, for example) (see Mayberry et al., 2021). Members of the Army and Air National Guard and other Reserve components (Army Reserve, Navy Reserve, Marine Corps Reserve, Air Force Reserve, Air National Guard, and Army National Guard), who generally serve part-time and augment the active-duty (full-time) military when needed, need to meet many of the same formal training requirements as their active-duty counterparts and have often served on active duty before joining National Guard or Reserve components (Military OneSource, 2024; Thomas, 2023). As such, many of the training and education programs referenced within the report are attended by members of multiple Services, including active-duty military, Guardsmen, and Reservists.

Treatment of Evidence

To author this report, the committee reviewed the existing literature, and at the start of the project it conducted a formal literature search to identify studies related to the statement of task. Throughout its deliberations, the committee discussed the types of evidence available and how the report would incorporate them. The committee elected to focus on research published within approximately the past five years, while also citing foundational studies when applicable. That way, the included evidence reflects the most up-to-date literature. The committee included a range of empirical evidence, including experimental, correlational, meta-analyses, and research reports. As mentioned previously, the National Academies has published several impactful consensus reports that review the evidence on learning science, and this report cites these as well. Given the similar area of work, the committee was careful to build upon and not replace the work these reports completed. In addition to these sources, the committee decided it was necessary to incorporate other forms of evidence to fully address the statement of task. This included citing military handbooks, publicly available government documents, papers in press, documents from the Services' websites, presentations from panelists during the public workshops, and papers that were relevant but not published in refereed outlets.

To understand the strengths and weaknesses of the evidence included in the report, the committee used the Tiers of Evidence framework from the Every Student Succeeds Act as a framework (Regional Educational Laboratory Midwest, 2019; Institute of Education Sciences, 2022), as well as recent frameworks for evaluating causal inference based on observational data (Diener et al., 2022; Foster, 2010; Grosz et al., 2020; Rohrer, 2018). The differential reliance on these two frameworks depended on the research question, the nature of the evidence, and the scope of the conclusions. For example, any notes regarding the strength of evidence for instructional approaches are mapped primarily onto the definitions included in the Tiers of Evidence framework, whereas comments on the strengths of evidence for developmental or motivational patterns depend more on the quality of observational data (e.g., availability of longitudinal data, well-characterized samples, replication across historical and cultural contexts). The committee articulates the types of evidence included and notes any limitation in context. For further discussion about evaluating the validity of evidence, see Chapter 7.

Organization of the Report

The report begins by focusing on contextual factors and then moves to the individual-level factors. Next, the committee examines learning technologies as well as assessments and evaluations. The organization of the report is designed to aid the reader and provide a logical flow of the body of evidence as well as the conclusions and recommendations. However, the committee notes that while the material is organized in this way, it recognizes there are no strict boundaries between these levels and topics. Rather, the committee believes that each area of work is deeply interconnected and related to the others.

Chapter 2 starts by articulating the military learning landscape for enlisted personnel, officers, and DoD civilians. As the chapter will show, these pathways define the formal training and educational contexts in the military. The chapter covers the competencies that most military learners are required to learn, as well as relevant policies and practices that inform who completes which formal programs, when, and for what purpose. The evidence on topics related to this context continues into Chapter 3, where the committee examines multiple learning contexts and the opportunities to bolster effectiveness. In that discussion, the fundamental principles of learning are reviewed, as well as the importance of learner autonomy and considerations of maximizing effective team learning contexts.

In Chapter 4, the report shifts from focusing on the learning contexts to taking a closer look at adult learners at the individual level. Here, the committee articulates how individual variation in cognitive skills, knowledge, dispositions, and motivation can shape the learning process, and how individuals change throughout the adult lifespan. In Chapter 5, the committee links the broader principles and findings of adult learning and ties them to several unique factors associated with the military context to understand what it means to be a military learner. This chapter includes considerations of stress, military cultural factors, equity factors, and career-related motivations at various points in a military career.

Chapters 2 through 5 address the first two sets of questions in the statement of task: (1) What are the motivations shaping learning in adults? How do motivations change (or not) throughout the lifespan and how do these changes impact learning behaviors? and (2) How do contextual and equity factors (including but not limited to task/situation, team, organizational, cultural, societal, and life cohort factors) shape the effectiveness of training and personnel policies and practices? Where is additional research needed?

The report's focus shifts in Chapter 6 to the third question in the statement of task: (3) What are the most promising topics related to emerging learning technologies for immediate investment and near-term payoff? This chapter builds on the general principles of adult learning to show how technologies can enhance them and discusses promising technology-enabled learning applications and the need for a strategic ecosystem-based approach. Chapter 7 covers approaches for assessing and evaluating adult learning. Here, the committee identifies the various purposes of assessment and evaluation, considers several important attributes, and reviews approaches to evaluation, focusing on the validity of inferences drawn from evaluation studies. This chapter covers the fourth set of questions in the statement of task: (4) What approaches to assessment and evaluation of adult learning and developmental outcomes are most effective? What deficiencies in the current approaches to assessment and evaluation might impede accurate measurement of learning and of developmental outcomes?

Finally, Chapter 8 presents the committee's conclusions, recommendations, and research agenda, outlining the areas needing future empirical work. This chapter directly responds to the fifth question in the statement of task: (5) What, if any, additional research investments should be made to better understand adult learning in the military context and to fully utilize contextual factors in achieving organizational effectiveness?

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2
Military Learning Pathways

The committee's task included examining how contextual and equity factors—including but not limited to task, situation, team, organizational, cultural, societal, and life cohort factors—shape the effectiveness of training and personnel policies and practices. To address this charge, the committee discussed the military learning pathways for enlisted personnel, officers, and Department of Defense (DoD) civilians. These pathways define the formal training and educational landscape in the military and represent the primary formal learning trajectories in the military context.

First, this chapter describes the context of military learning by reviewing key values of the military environment that underlie all learning pathways across the military and may inform how adult learners navigate the learning landscape. It then provides an overview of the competencies most military learners are required to learn and discusses specifics by pathways. The committee's description of the separate pathways includes a brief overview of key DoD personnel policies and practices regarding recruitment, selection, classification, and promotion that provide context for military learning in terms of who completes which formal training and education programs, when, and for what purpose.

VALUES IN THE MILITARY CONTEXT: UNDERLYING MILITARY TRAINING AND EDUCATION PATHWAYS

The training and educational landscape in the U.S. military is large, varied, and complex. The entire military, including these learning pathways, is governed not only by rules and regulations but also by core values that help define several key characteristics of the military learning environment. DoD espouses the values of duty, ethics, honor, integrity, courage, and loyalty (Mattox, 2013). In addition, as Box 2-1 illustrates, each of the Services has its own core values. The values that exist across DoD and within the Services are not just preferences, but are collectively embraced and are enduring principles that provide fundamental guidance. In other words, military learners are expected to adopt and live by these values (Schwartz, 1999; Military Leadership Diversity Commission, 2009).

BOX 2-1

Core Values of the Department of Defense and the Services

DoD: Duty, integrity, ethics, honor, courage, and loyalty

Air Force: Integrity first, service before self, and excellence in all we do

Army: Loyalty, duty, respect, selfless service, honor, integrity, and personal courage

Coast Guard: Honor, respect, and devotion to duty

Marine Corps: Honor, courage, and commitment

Navy: Honor, courage, and commitment

Space Force: Character, connection, commitment, and courage

SOURCE: Military Leadership Diversity Commission, 2009; U.S. Space Force, 2023

Researchers have studied culture across a number of organizational and educational contexts, including the military (Hofstede, 1980; Milheim, 2017; Soeters et al., 2006). While culture has varied definitions (Raeff et al., 2020), an organization's culture includes the communal embodiment of the organization's values, its philosophy, traditions, language, and rules in relationship with its members to give meaning to the organization (Bass & Bass, 2009; Schein, 2010). A strong value system is a core part of the military culture and distinguishes the military context from many civilian learning contexts (Halvorson, 2010; Redmond et al., 2015). Values and the larger culture inform how individuals behave by shaping how individuals may interpret situations, make everyday decisions, and ultimately navigate their learning pathways (Bourne & Jenkins, 2013; Schwartz, 1999; Wilson, 2008).

WHAT IS LEARNED: COMPETENCIES IN THE MILITARY

Learning is a process of acquiring competencies for subsequent application that is appropriate to the context (see Chapter 1 for terminology and Chapter 4 for more on learning). The National Academies' *How People Learn II* report discusses six types of learning (National Academies, 2018): habit forming and conditioning, observational learning, implicit pattern learning, perceptual and motor learning, learning of facts, and learning by making inferences. Military learners engage in all these types of learning as they make their way through their formal pathway. For instance, learning to reload a weapon can happen with perceptual and motor learning. As military learners make their way through various learning pathways, there are a number of desired competencies that military organizations aim to impart along the way (see Table 2-1) that tend to increase in complexity from tactical to strategic.

TABLE 2-1 Committee's Mapping of Competencies with Examples

COMPETENCIES	
Hard Skills	**Soft Skills**
• Tactical skills: demonstrate the loading, charging, reloading, and unloading of a weapon. • Motor skills: demonstrate drill movements on command. • 21st Century Skills: Cognitive- knowledge, cognitive processes	• Attitudes, values, and habits: understand followership is as equally important as leadership. • 21st Century Skills: Intrapersonal- intellectual openness, work ethic, positive core self-evaluation Interpersonal-teamwork, collaboration, leadership

SOURCES: Committee generated, with examples from National Research Council (2012); *Basic Military Training*, U.S. Department of the Air Force (n.d.).

Under the umbrella of soft skills, military learners are expected to learn attitudes, habits, and the values discussed in Box 2-1. The focus on these values may be where military learning contexts differ the most from many civilian learning contexts. For example, soft skills may include attitudes regarding personal morality or courage. Habits such as personal organization are also expected to be learned by requiring behaviors such as displaying uniforms or folding clothes in a specific standardized manner (*Basic military training*, U.S. Department of the Air Force, n.d.).

The expectation to learn specific attitudes or values to fit into the military context may challenge some military learners. Adults bring their varied and unique backgrounds, identities, lived experiences, language variations, and other personal identities into organizations (Lutz, 2013; McCluney & Rabelo, 2019; Yamauchi et al., 2016). Basic military training attempts to level the playing field by creating a period of assimilation into the U.S. military community (Hinote et al., 2015; Redmond, 2015; Zurcher, 1967). However, military learners who come from backgrounds or hold ideals that are not a clear “fit” with the nature of the military context may face a challenge in trying to assimilate into the military, which may affect both learners and instructors (Figueroa & Rodriguez, 2015; Verquer et al., 2003). Chapter 5 discusses equity and motivational factors that may shape the effectiveness of military training.

The last two domains of soft skills—intrapersonal and interpersonal competencies—have been identified as important for military learners. For example, recent large-scale studies identified competencies from the Army Talent Attribute Framework (Army Talent, n.d.) deemed most important for enlisted personnel (E5–E9) and officers (O1–O5) by rank (Royston & Amey, 2023; Royston & Lin, 2023). Among the possible 196 competencies, the top 40 identified as important for enlisted personnel and officers included several soft skills, or those that are intrapersonal and interpersonal in nature. Examples from the top 40 include the following:

- Adaptability
- Initiative
- Communication Ability
- Emotional Control
- Cooperation/Teamwork

Under the umbrella of hard skills, many military learners are expected to learn tactical skills, which may include a range of specific behaviors such as those related to marksmanship, grenade usage, and land navigation (*Preparing for the Operating Forces*, U.S. Marine Corps, n.d.). Relatedly, the domain of hard skills includes other motor skills, such as those reflected in routine fitness tests (e.g., two-mile run or a standing power throw (*Army Combat Fitness Test*, U.S. Army, n.d.)). Finally, the cognitive domain captures a number of competencies that are related to fluid intelligence, crystallized intelligence, and broad cognitive speediness (National Research Council, 2012).

As stated, the competencies of what is to be learned across the military pathways largely fall within the classification noted in Table 2-1. As the upcoming sections will articulate, there are variations regarding which competencies are learned by whom, and at what point they are learned in a career lifespan.

MILITARY TRAINING AND EDUCATION PATHWAYS[2]

Training and education pathways are differentiated primarily by three core groups of military learners: enlisted personnel, officers, and DoD civilians. The pathways for enlisted personnel and officers differ markedly, but each follows its own defined route. Along these defined pathways, there are some variations in training based on an individual's assigned occupation. Both enlisted personnel and officers are affected by the U.S. military's "up-or-out" promotion policies, which means military members need to be promoted within a certain amount of time, and if they do not meet those promotional milestones they are required to leave the Service (Congressional Research Service, 2022; National Academies, 2021; Rostker et al., 1993). The military enacted these up-or-out promotional policies with the intention of attracting and maintaining a high-quality force by building a culture defined by achievement and success (Schirmer et al., 2005). While there have been adjustments to policies throughout the Services, up-or-out largely remains in effect (National Academies, 2021).

Consistent with these policies, enlisted personnel and officers are generally required to pursue continued education to progress through the ranks and stay in the military. Further, military members are typically assigned to a given position for no more than four years before being reassigned through a centralized process. As for the final core group, DoD civilians, the term "pathway" is not fully applicable in describing their education and training trajectory. As this upcoming section will demonstrate, the pathway tends to be inconsistent and not as formally structured compared to enlisted and officer pathways.

For each of the three groups, the committee describes the pathways and the relevant personnel policies that may impact the training and/or education of each group, and then discusses the specific competencies that military organizations aim to instill in their learners as they make their way through. The material and examples included in the upcoming sections is not meant to be exhaustive but rather illustrative in demonstrating cross-cutting trends across the military.

[2]This section and the sections that follow draw directly from an expert review the committee commissioned (Laurence, 2024).

Enlisted Pathways

Enlisted personnel typically enter the military without a college degree or prior specialized career training. In addition to medical and physical requirements for enlistment, recruits are required to successfully pass criminal background checks, possess a high school diploma or high school equivalency (GED) certificate, and meet cognitive screening requirements (Matthews, 2017). Recruits with college credits or other experience may be eligible to enter the military at a higher rank (E-2, E-3, or E-4)[3] than other recruits, who enter as E-1s.

Recruits sign an enlistment contract that obligates them to complete a period of enlistment. By law, all enlistees agree to a total military service obligation of eight years, including time on active duty and inactive time (on-call) in the Individual Ready Reserve (*DoDI 1304.25*, U.S. DoD, 2021). Although the length of the active duty service commitment varies, a four-year full-time commitment is most common. However, in the face of recent recruiting challenges (Garamone, 2023), the Army has recently reduced the minimum active duty service commitment to two years (Figgs, 2022).

The Armed Forces Qualification Test (AFQT), a composite based on the Armed Services Vocational Aptitude Battery (ASVAB) math and verbal subtests, determines eligibility to enter the military (Velgach, 2022). Minimum AFQT scores vary by Service, with higher AFQT scores required for recruits who have obtained a GED certificate in lieu of a high school diploma (Velgach, 2022). After initial screening with the AFQT, the military uses the ASVAB for classification into a specific military occupation (termed Military Occupational Specialty [MOS] in the Army and Marine Corps, Air Force Specialty, and Navy ratings). Higher ASVAB scores enable recruits to qualify for more military occupations, increasing the likelihood that recruits will be able to train for a desired occupation (Velgach, 2022). Although qualification for many military occupations, such as human resources, is based on math and verbal subtest scores alone, qualification for some military occupations, such as aircraft mechanic, explosive ordnance technician, and carpentry specialist, is based partly on other ASVAB subtests. Some examples of subtests include Mechanical Comprehension, Electronics Information, and Auto and Shop Information (Velgach, 2022).

[3]The Services use the same “E-” designation for enlisted pay grades, with Service-specific names, such as chief petty officer (E-7) or corporal (E-4).

In some cases, recruits may be assigned to enter the military to train for a given occupation because of immediate class seat availability without understanding the wide array of military occupations available or how their own vocational interests align with those occupations (Johnson et al., 2020). In recent years, the Services have invested in developing and validating tailored vocational interest assessments, including, for instance, the Job Opportunities in the Navy, the Air Force Work Interest Navigator, and the Army's Adaptative Vocational Interest Diagnostic (AVID) tools. Research has demonstrated significant relationships between these fit metrics and criteria such as first-term attrition, re-enlistment decisions, early promotion, and job satisfaction (Johnson et al., 2020; Kirkendall et al., 2020; Watson, 2020), but the status of implementing these tools varies, and there is typically no guarantee that a given individual will be assigned into a military occupational specialty aligned with their interests.

Since 2018, the Navy has required administering its vocational interest tool during recruit classification and has a formalized process for using the results to match recruits to available occupations (Crenshaw, 2018; Watson, 2020). The Air Force made its vocational interest assessment available publicly as an optional tool for individuals who are considering enlisting[4] and as an optional tool for in-service enlisted members who are considering retraining into a different enlisted occupation (Salomon, 2018). The Army has not yet implemented a validated vocational interest assessment in recruiting or retraining, and as of this writing, the public-facing Army recruiting website (goarmy.com) features a four-question "Army Career Match" quiz, rather than the more in-depth, validated vocational interest assessment (AVID) that the Army Research Institute has developed.

Initial Entry Training (Basic Training and Technical Training)

Upon enlisting, recruits take part in basic military training or "boot camp," which includes both classroom and field training. The duration varies by Service, but has common elements, including physical conditioning/training, socialization, and acculturation to values. Recycling, where recruits are required to repeat a phase of training, is not uncommon and is typically a result of injury or failure to meet certain milestones. With limited exceptions, recruits receive technical training in preparation for their military occupational specialty following basic military training.

[4] Available at https://my.airforce.com/myaf_loginPage

The skills that enlisted recruits learn before entering their first job assignment are primarily occupation-specific. For example, medics, aircraft mechanics, foreign language translators, intelligence analysts, air traffic controllers, military police, or instructors, each perform different functions and need to learn different types of skills and bodies of knowledge. Like students in civilian vocational education programs, recruits are generally not expected to have prior knowledge or experience related to an occupational field before entry, and as such, the military often provides substantial technical training before members begin on-the-job training (*AETCI 36-2651*, Air Education and Training Command, 2023).

Technical training is as varied as the occupations requiring further training. Thus, as Table 2-2 depicts, the length of initial technical training depends on the specific occupation, ranging from four weeks to more than one year. For example, in the Navy, a minority of new sailors may go on, beyond the initial period of technical training, to attend so-called “C-School,” where they receive highly specialized training in one specific task, such as operating a Tomahawk missile system.

TABLE 2-2 Initial Entry Training for Enlisted Personnel

	Required of all enlistees, (regardless of occupation)	**Occupationally specific training**
Army [a]	Basic Combat Training • 10 weeks	One Station Unit Training • For combat and military police occupations • 13–19 weeks OR Advanced Individual Training • For occupations that do not attend One Station Unit Training • 4–52 weeks
Navy [b]	Boot Camp • 8 weeks	Technical Training: Apprentice Training (A-School) • 4–63 weeks AND (for select occupations only) Specialty Training (C-School) • 2–58 weeks
Marine Corps [c]	Boot Camp • 13 weeks AND	Military Occupational Specialty School • 4–54 weeks

	School of Infantry • 14 weeks	
Air Force [d]	Basic Military Training: • 7 weeks	Technical Training • 6–72 weeks
Space Force [e]	Basic Military Training: • 7.5 weeks	Technical Training • 8–28 weeks

SOURCE: Laurence (2024).
NOTE:
a U.S. Department of the Army (2014), *The Soldier's Blue Book: The Guide for Initial Entry Training Soldiers.*
b U.S. Navy Recruit Training Command (n.d.), Basic Military Training Schedule.
c Sanchez (2023), Marine Corps MOS School Length: A Detailed Overview.
d U.S. Department of the Air Force, (n.d.), Basic Military Training.
e U.S. Space Force (n.d.), Training; U.S. Space Force (n.d.), Careers.

Formal Training and Education Requirements for Enlisted Promotion Eligibility

Members continue to be shaped as part of an effective force beyond initial training. Within each of the Services, promotion policies that inform progression to and through the ranks vary and are subject to frequent change. Table 2-3 shows the titles associated with each level and rank across the Services. Though the details may vary slightly between the Services, the promotional criteria are similar, relying on time in grade, time in service, and meeting training requirements pertinent to the military member's occupation. Further, many are required to pursue Professional Military Education, which generally refers to a collection of formalized programs to advance an individual's development and learning. Professional Military Education tends to focus on future work challenges that are not yet fully known (for the Army, see *AR 600-8-19*, U.S. Department of the Army, 2023; and for the Navy see *SECNAVINST 1400.1*, U.S. Secretary of the Navy, 2019, and *SECNAVINST 1412.8*, U.S. Secretary of the Navy, 2019).

However, not all who enlist continue in service beyond their obligation, and some are promoted to positions of authority. Career progression and advancement up to the rank of E-4 is generally automatic based on tenure, which includes time in service, time in grade, and commander approval. However, progression to the ranks of E-5 and above depends on competitive promotion via promotion boards, where a panel evaluates candidates based on performance appraisals and other achievements or the assignment of points based on standardized criteria such as quantitative performance ratings, physical fitness test scores, military or occupational knowledge test scores, and tenure (Williamson, 1999). Beyond the rank of E-4, promotion eligibility typically requires completing rank-specific Professional Military Education and occupation-specific upgrade training (see Williamson, 1999). See Appendix C for an illustrative example of time requirements and Professional Military Education requirements needed for Air Force promotion eligibility.

TABLE 2-3 Enlisted Level/Rank

Enlisted Level	**Army**	**Navy**	**Marine Corps**	**Air Force**	**Space Force**
E-1	Private	Seaman, Fireman, Airman, Construction, or Hospital Recruit	Private	Airman Basic	Specialist 1
E-2	Private	Seaman, Fireman, Airman, Construction, or Hospital Apprentice	Private First Class	Airman	Specialist 2
E-3	Private First Class	Seaman, Fireman, Airman, Constructionman, or Hospitalman	Lance Corporal	Airman First Class	Specialist 3
E-4	Corporal or Specialist	Petty Officer Third Class	Corporal	Senior Airman	Specialist 4
E-5	Sergeant	Petty Officer Second Class	Sergeant	Staff Sergeant	Sergeant
E-6	Staff Sergeant	Petty Officer First Class	Staff Sergeant	Technical Sergeant	Technical Sergeant
E-7	Sergeant First Class	Chief Petty Officer	Gunnery Sergeant	Master Sergeant	Master Sergeant
E-8	Master Sergeant or First Sergeant	Senior Chief Petty Officer	Master Sergeant or First Sergeant	Senior Master Sergeant	Senior Master Sergeant
E-9	Sergeant Major or Command	Master Chief Petty Officer	Master Gunnery Sergeant or	Chief Master Sergeant	Chief Master Sergeant

	Sergeant Major		Sergeant Major		

SOURCE: Adapted from *Population Representation in the Military Services: Fiscal Year 2020 Summary Report,* U.S. DoD (2023). See also https://www.spaceforce.mil/News/Article/2487814/space-force-releases-service-specific-rank-names/
NOTE: No personnel were assigned to the Space Force until Fiscal Year 2021 (Space Force was established December 19, 2019; see https://www.spaceforce.mil/About-Us/About-Space-Force/History/.

Enlisted Professional Military Education

As discussed in Chapter 1, the military services distinguish between the terms "training" and "education." Although military training is primarily occupation-specific and prepares personnel to perform specific tasks or specific job requirements, education is viewed as broader preparation for unknown future situations (see Army Learning Concept, 2017; DAFI 36-2670, *Total Force Development;* MCO 1553.1B, *The Marine Corps Training & Education*). As such, Professional Military Education programs offered by each of the Services typically emphasize broader development in areas such as leadership, ethics, and (at the most senior ranks) strategic thinking.

Unlike formal military training, which is primarily occupation-specific, individuals from varied and distinct occupations typically attend the same Professional Military Education programs together. Instead of the occupation determining who attends training, Professional Military Education programs are typically designed for specific ranks, with each of the Services requiring military members to complete Professional Military Education to advance to certain ranks.

Although enlisted Professional Military Education varies by Service, each Service offers courses at the primary (E4-E6), intermediate (E-6/E-7), senior (E-8/E-9), and executive (E-9) levels. Across this continuum of learning, curricula progress from a focus on the tactical or operational level (Primary and Intermediate Professional Military Education) toward a broader focus on warfighting at a strategic level (Senior and Executive Professional Military Education) (*CJCSI 1805.01C*, U.S. Joint Chiefs of Staff, 2021). For example, within the Army, promotion to the rank of E-5 requires completion of a four-week Basic Leader Course, which includes curriculum on leadership and management, communication, and interpersonal skills. Army Professional Military Education programs required for the subsequent ranks of E-6 and E-7 (Advanced Leader Course and Senior Leader Course) continue to focus on leadership and management, communication, and interpersonal skills, but emphasize different aspects within those domains. For example, while the Basic Leader Course introduces the fundamentals of writing and public speaking, the Advanced and Senior Leader Courses include instruction on persuasive and influential communication (*CJCSI 1805.01C*, U.S. Joint Chiefs of Staff, 2021).

Enlisted Occupation-Related Training

While the precise evaluation and certification processes may differ, each military occupation has training standards that military members are required to complete for promotion eligibility. The Navy and Air Force also require enlisted personnel to complete standardized knowledge tests outside of the training environment to compete for promotion (see *NAVPERS 18068F*, U.S. Department of the Navy, 2024, for example), though the Army does not (see *AR 600-8-19*, U.S. Department of the Army, 2024, for regulations within the Army). Instead, the Army generally evaluates occupation-specific skills at the unit level, and not institutionally. Individual units determine the competencies their members need, and they assess them in their own way. As such, unit leaders can, and often do, report on skill competency in their performance reviews. In addition, when the Army considers individuals for promotion, the promotion board will test occupation-specific competence, though not in an institutionally mandated formalized process such as a skills test. It is still the case that, as with the other Services, promotion to E5 and E6 in the Army will include additional occupationally specific training.

The Air Force serves as an example illustrating the learning objectives usually required in occupation-specific training. In the Air Force, Career Field Education and Training Plans specify the tasks members complete through on-the-job training and the levels of knowledge and task proficiency that members demonstrate formally in career development course exams and upgrade training courses to progress from the Apprentice to Journeyman and Craftsman levels. Table 2-4 provides an example of a proficiency code key, while Table 2-5 provides examples of occupational knowledge and the tasks that members of the Security Forces career field demonstrate at the Apprentice level and the Journeyman and Craftsman levels. As shown, in some cases the members demonstrate the same tasks or knowledge domains in initial technical training and upgrade training, though the minimum acceptable level of proficiency increases. In other cases, the members only need to demonstrate general subject matter knowledge in initial technical training, but Journeymen and Craftsmen are expected to perform tasks associated with the subject matter domain.

TABLE 2-4 Proficiency Code Key Example

Proficiency Code Key		
	Scale value	Definition: The learner . . .
Task Performance Levels	1	Can do simple parts of the task. Needs to be told or shown how to do most of the task. (extremely limited)
	2	Can do most parts of the task. Needs only help on hardest parts. (partially proficient)
	3	Can do all parts of the task. Needs only a spot check of completed work. (competent)
	4	Can do the complete task quickly and accurately. Can tell or show others how to do the task. (highly proficient)
Task Knowledge Levels	a	Can name parts, tools, and simple facts about the task. (nomenclature)
	b	Can determine step-by-step procedures for doing the task. (procedures)
	c	Can identify why and when the task must be done and why each step is needed. (operating principles)
	d	Can predict, isolate, and resolve problems about the task. (advanced theory)
Subject Knowledge Levels	A	Can identify basic facts and terms about the subject. (facts)
	B	Can identify relationship of basic facts and state general principles about the subject. (principles)
	C	Can analyze facts and principles and draw conclusions about the subject. (analysis)
	D	Can evaluate conditions and make proper decisions about the subject. (evaluation)

SOURCE: *CFETP 3P0X1AB*, U.S. Department of the Air Force (2023).

TABLE 2-5 Example of Occupational Knowledge and Skill Requirements (Security Forces)

	Apprentice level	Journeyman level	Craftsman level
Task Knowledge and Task Performance			
Service pistol qualification	3c	--	--
Participate in or lead stress drills	1a	2b	3c
Perform casualty care and evacuation	2b	3c	--
React to bomb threat	2b	3b	3c
Conduct preventative maintenance checks	--	3b	--
Lead fire team movements	--	3c	3c
Subject Knowledge			

Bloodborne pathogens	A	--	--
Building searches	A	2b	3c
Secure a crime scene / protect evidence	A	3c	--
Media and social media relations	A	B	B
Pyrotechnics/ flares	A	B	C
Sensor operations and unmanned systems	--	B	C

SOURCE: *CFETP 3P0X1AB*, U.S. Department of the Air Force (2023).
NOTE: The letters and numbers correspond to the proficiency codes listed in Table 2-4

Other Enlisted Training and Education

In addition to the major training and education pathways for enlisted personnel, there are other notable opportunities. To illustrate, Special Operations forces receive rigorous training. Each of the Services selects elite forces from among enlisted and officer volunteers for such units. An example includes the Navy SEALS. Some of these special training programs can be completed without being part of the specialized unit. For example, Army soldiers can complete Ranger school without being part of the Ranger regiment. Completing such courses can count toward promotion in a promotion points system (*AR 600-8-19*, U.S. Department of the Army, 2023).

Self-development is yet another category of military education. Members of each of the Services can voluntarily attend college and complete certificates and degrees that serve them well during their military service and beyond. Most enlisted personnel (approximately 80%) do not have a college degree (*2020 Demographics: Profile of the Military Community*, U.S. DoD, 2020). In their off-duty time, members may pursue undergraduate and master's degrees through DoD's tuition assistance program (Absher, 2023) or by using their GI Bill benefits (U.S. Department of Veterans Affairs, 2024). Community college is also an option. For instance, courses are available through the U.S. Naval Community College[5] and the Air Force hosts the Community College of the Air Force (Air University, 2022), which awards an Associate of Applied Science degree.

The Army, Marine Corps, and Air Force have formally incentivized pursuing additional training or education through their enlisted promotion systems for certain ranks. For E-5 and E-6

[5] https://www.usncc.edu/s/academics/available-programs

promotions, the Army awards points for civilian college credits, with additional points for degree completion, technical certifications, and a wide variety of other in-residence and online military training courses, including asynchronous courses freely accessible through the Army e-Learning platform (*AR 600-8-19*, U.S. Department of the Army, 2023). Similarly, the Marine Corps has awarded points toward E-4 and E-5 promotions for completing civilian college courses and a variety of freely accessible military online courses (*MCO P1400.32D*, Commandant of the U.S. Marine Corps, 2012). Though not required for promotion, earning these Army and Marine Corps bonus points for self-education can compensate for other promotion factors, such as tenure, performance ratings, physical fitness, or weapons proficiency test scores.

Though the Air Force does award promotion points for self-education, it requires an associate's degree for promotion eligibility to E-8 (Nichols, 2019). The associate's degree may be from either a civilian institution or from the Community College of the Air Force. Typically, most enlisted members earn about half of the Community College of the Air Force credit hours through mandatory training required for their occupational specialty, but attaining a degree requires additional credits in general education, management, and program electives (Hetrick, 2016). Although the Navy and Air Force do not award promotion points directly for additional education and training, their enlisted promotion systems require substantial self-study for technical knowledge tests related to their service and occupational specialty or rating (Navy-wide Advancement Exams for promotion to E-4 through E-7; Air Force Specialty Knowledge and Promotion Fitness Exams for promotion to E-5 and E-6).

Officer Pathways

Entry into the Military as an Officer

This section reviews the major pathways for officers. Individuals may enter the military as officers, typically at the rank of O-1 but potentially higher (e.g., O-2 or O-3) depending on prior civilian qualifications through a number of distinct paths or "commissioning sources." Individuals already serving in the military as enlisted personnel may also apply to become an officer while in service. Each of these entry points generally requires a minimum of a 4-year college degree.

The most common pathways to becoming an officer are through the military service academies, Reserve Officers' Training Corps (ROTC), or Officer Candidate School (termed

Officer Training School in the Air Force). Admission to the military service academies is highly competitive. If selected—typically through a Congressional nomination process—Service academy students earn a 4-year college degree from an elite institution with high academic standards and a rigorous core science, technology, engineering, and mathematics curriculum, while also completing military training requirements and physical requirements. Cadets and midshipmen typically make a military service commitment after two years at the academies, and enter into the respective military service immediately upon graduation.

In contrast, the Army, Navy, and Air Force offer ROTC programs at more than 200 civilian colleges and universities geographically dispersed across the country. Through these programs, participants can graduate with a degree from the civilian college or university in any academic major, but are required to complete specific military courses during the school year. Initial ROTC courses are open to any civilian student, and cadets do not make a military service commitment until after they attend military field training or accept an ROTC college scholarship.

Finally, as an alternative to the military service academies and ROTC programs, civilians who did not complete military training or education while in college may apply to enter into the military to attend Officer Candidate School directly. For instance, Marine Corps officer candidates attend Platoon Leaders Course (or Officer Candidate Course) as an alternative to Navy ROTC. In addition to technical and professional skills, precommissioning military training, regardless of whether it is offered through the military service academies, ROTC, Officer Candidate School, or Officer Training School, includes instruction on topics such as traditions, ceremony, athletics, and discipline.

Officer Classification into Occupation

There are nearly as many distinct occupational specialties for military officers as there are for enlisted personnel. In contrast to enlisted classification, some officer specialties require a specific academic major or advanced degree for entry, such as engineering, nursing, or law. Depending on their assigned occupational specialty, officers may need to complete lengthy technical training upon commissioning, for example to become a pilot or nuclear operations officer. Cadets and midshipmen entering from the military service academies or ROTC typically make a military service commitment before they are classified into an occupational specialty. Although cadet and midshipman preferences are given weight in classification, there is typically no guarantee that a cadet or midshipman will be placed into their desired occupational specialty.

Faculty or other mentors at the military service academies and ROTC detachments may advise cadets and midshipmen when they prepare their rank-ordered list of preferred occupational specialties, but particularly at ROTC detachments, cadets and midshipmen may not always have access to mentors with deep knowledge of specific occupational specialties. As is the case for enlisted personnel, the Air Force has introduced an optional vocational interest tool that provides recommendations for matching to specific officer occupations (Air Force Personnel Center, 2023).

Table 2-6 shows officer titles and ranks. Notably, the majority of officers fall within paygrades O-1 through O-3. Few advance beyond O-6 and become “flag” officers or “general” officers in the Army, Air Force, and Marines or admirals in the Navy and Coast Guard. For instance, it takes more than 20 years to become a full colonel in the Army, Air Force, and Marines or a captain in the Navy.

TABLE 2-6 Officer Level/Rank

Officer Level	Army	Navy	Marine Corps	Air Force	Space Force
O-1	Second Lieutenant	Ensign	Second Lieutenant	Second Lieutenant	Second Lieutenant
O-2	First Lieutenant	Lieutenant Junior Grade	First Lieutenant	First Lieutenant	First Lieutenant
O-3	Captain	Lieutenant	Captain	Captain	Captain
O-4	Major	Lieutenant Commander	Major	Major	Major
O-5	Lieutenant Colonel	Commander	Lieutenant Colonel	Lieutenant Colonel	Lieutenant Colonel
O-6	Colonel	Captain	Colonel	Colonel	Colonel
O-7	Brigadier General	Rear Admiral Lower Half	Brigadier General	Brigadier General	Brigadier General
O-8	Major General	Rear Admiral Upper Half	Major General	Major General	Major General
O-9	Lieutenant General	Vice Admiral	Lieutenant General	Lieutenant General	Lieutenant General
O-10	General	Admiral	General	General	General

SOURCE: *OPA Report # 2023-019*, U.S. DoD (2023); *Space force releases service-specific rank names*, U.S. Space Force (2021).

Officer Professional Military Education

To continue service and compete for promotion, officers are required to complete requisite Professional Military Education programs at several points in their careers. Such educational opportunities take place at junior, intermediate, and senior levels. The goal is to provide leadership knowledge, skills, and abilities at increasingly higher levels, from tactical through strategic, as military members proceed from unit-level leaders and on to senior level generals and admirals (Case et al., 2021; *AR 600-8-19*, U.S. Department of the Army, 2023; Orsi, 2017).

The first encounter with Professional Military Education occurs at one of the service academies, ROTC, Office Candidate School, or Officer Training School (Goldman et al., 2024). Upon commissioning, officers are prepared for increasing levels of responsibility and command. Table 2-7 highlights the Professional Military Education and grade levels for officers. The content typically includes military history, ethics, critical thinking, communication, problem solving, and leadership. Most officers complete Professional Military Education via distance learning, with select officers attending in-residence intermediate and senior Professional Military Education programs, typically lasting for 10 months. Top performers are more likely to attend Professional Military Education in person (Orsi, 2017). Intermediate-level graduates may earn a master's degree in fields such as Military Operational Art and Science or Defense and Strategic Studies (e.g. *JPME Phase I & Master's Degree*, U.S. Naval War College, n.d.).

TABLE 2-7 Professional Military Education Levels for Commissioned Officers

Level	**Grade**	**Typical time in service**	**Approximate average age**
Precommissioning	Before O-1	--	
Primary	O-1 to O-3	1–5 years	23–27
Intermediate Professional Military Education - I	O-4	10–17 years	33–39
Senior Professional Military Education - II	O-5 to O-6	17–22 years	39–45
General/Flag Officer *Capstone at National Defense University*	O-7+		

SOURCES: Goldman et al. (2024); *Pamphlet 600–3*, U.S. Department of the Army (2010).

Joint Professional Military Education is provided at the intermediate and senior levels to prepare officers to work across the Services and train them to take on interagency leadership and management positions. Senior Professional Military Education may be completed at either the officers' home Service school—Army officers may attend Army War College, for example—or at other Services' colleges, such as the Marine Corps War College, U.S. joint-Service colleges such as the National War College, or at select international military institutions. To an increasing extent, senior Professional Military Education emphasizes national security strategy and a whole-of-government approach, drawing from fields such as international relations, political science, and economics. Senior Professional Military Education requires officer preparation on broad

Joint Learning Areas, Desired Leader Attributes, and Professional Military Education outcomes such as strategic thinking, communication, ethical decision-making, and leadership (see Table 2-8 for an example crosswalk for one of these desired learning outcomes; additional information is in Appendix C and in Chapter 7). In addition, preparation is needed in special areas of emphasis that may relate more directly to understanding specific challenges identified by the current National Defense Strategy or National Military Strategy, such as great power competition and space as a warfighting domain (*CJCSI 1800.01F*, U.S. Joint Chiefs of Staff, 2020).

TABLE 2-8 Example of Desired Outcomes of Senior Professional Military Education, Including Joint Learning Areas and Desired Leader Attributes

Joint Learning Area (JLA)	Desired Leader Attributes (DLA) and Professional Military Education Outcomes
JLA #1: Strategic Thinking and Communications • Demonstrate advanced cognitive and communication skills employing critical, creative, and systematic thought. • Evaluate alternative perspectives and demonstrate the ability to distinguish reliable from unreliable information to reasoned decisions. • Persuasively communicate on behalf of their organizations with a wide range of domestic and foreign audiences. • Through communication, synthesize all elements of their strategic thinking concisely, coherently, and comprehensively in a manner appropriate for the intended audience and environment.	• **DLA #6:** Think critically and strategically in applying joint warfighting principles and concepts of joint operations." • **Professional Military Education Outcome #5:** Demonstrate critical and creative thinking skills, interpersonal skills, and effective written, verbal, and visual communications skills to support the development and implementation of strategies and complex operations.

SOURCE: Committee generated, text verbatim from *CSJCI 1800.01F*, U.S. Joint Chiefs of Staff (2020).

Officer Technical and Professional Education

Earning a civilian degree while on duty is also possible. The military operates specialized, technical institutions that award certificates and degrees to officers at the intermediate career stage. For example, officers in particular specialty areas may be selected to attend the U.S. Army Armament Graduate School, Air Force Institute of Technology, Naval Postgraduate School, or Joint Special Operations University. Some officers in designated areas may be selected to earn advanced degrees, including doctorates at civilian schools through fully-or partially-funded programs. Finally, there are opportunities for nonsponsored self-development for which officers may choose to use their veteran's benefits (*DA PAM 600-3*, U.S. Department of the Army, 2023).

DoD Civilian Pathways

This final section discusses the pathway for DoD civilians, who are non-uniformed members of the military. Currently, there are more than 770,000 DoD civilians in the military, and 48 percent of civilians served in the military before entering civil service (*GAO-20-592*, U.S. GAO, 2020). This pattern is consistent with federal personnel policies such as hiring preferences for veterans and crediting military service towards civil service retirement (Brown, 2019; *Federal Retirement*, U.S. Office of Personnel Management, n.d.). As such, training and education of the enlisted and officer corps can have long-term implications for the competencies and behaviors of the DoD civilian workforce.

DoD Civilian Personnel Policies and Practices

DoD organizations may hire civilians for a specific job position. Typically, DoD expects these civilians to be fully qualified for the position based on relevant prior education, training, or experience. Unlike enlisted personnel and officers, DoD civilians may continue working for the military indefinitely; there is no mandatory retirement age for most DoD civilian positions (Rayworth, 2022). Termination of federal employees is rare—only 2 percent of employees are terminated within their probationary period (Werber et al., 2023)—and DoD civilians view their jobs as providing substantially more job security and stability than those in the private sector (Orvis et al., 2022). In the event an organization determines a position is no longer needed, the organization typically offers civilian employees a reassignment at the same pay rate (*Summary of Reassignment*, U.S. Office of Personnel Management, n.d.).

In contrast to military members, who are required to change jobs frequently, this is rarely required for DoD civilians. With few exceptions, DoD civilians are not under contract, do not have a minimum service commitment, and may choose to terminate their employment at any time.

In addition, DoD civilians are not required, as military members are, to be promoted to roles with higher levels of responsibility to continue their employment with DoD. Rather, the most common approach for DoD civilians who seek to be promoted is to apply for specific open positions that have a higher pay grade, though there are organizations within DoD that offer promotion in-place opportunities based on performance and merit in an effort to reward exceptional work and to retain world-class talent.

DoD Civilian Training and Education

Although DoD civilians are expected to engage in professional development, participation in centrally managed training and education programs is typically at the discretion of the employee and their local supervisor. For example, although DoD civilians may participate in the same officer Professional Military Education courses as their military member counterparts, Professional Military Education completion is not required for DoD civilians to be promoted (Goldman et al., 2024).

Mandatory DoD-wide or Service-wide training for DoD civilians is relatively limited. DoD civilian managers and supervisors are required to complete mandatory training within one year of their initial appointment to a supervisory position and at least once every three years thereafter (*2019 DoD Managerial and Supervisory Learning and Evaluation Framework*, Defense Civilian Personnel Advisory Service, 2019). By law, this mandatory civilian training needs to address specific topics, such as conducting performance appraisals, employee rights, and prohibited personnel practices, but DoD does not require in-person or synchronous training or a minimum number of training hours. For example, the Army University's civilian supervisor development course is a 40-hour, self-paced online course, and the refresher course is 16 hours self-paced (Army Management Staff College, 2024).), Most DoD-wide or service-wide training requirements for civilians are brief, one-time or annual requirements that employees can often complete in an hour or less (e.g., cyber awareness and sexual assault prevention training; see *Mandatory training resources,* U.S. Army, n.d.).

Though typically not mandated, training, education, and professional development programs are abundant for DoD civilians (*DoDI 1400.25-V410*, U.S. DoD, 2013), and DoD civilians often perceive their professional development opportunities as a key benefit of DoD civilian employment (Orvis et al., 2022). In addition to DoD's civilian leadership development programs, each of the Services has such programs for civilians that work for the Services directly (Culkin, 2022). Furthermore, civilians may be selected to participate in other programs for particular career fields. Intelligence, acquisition, law, and health care are examples of areas in which civilians may be selected for further education and training. In addition to leadership development and career field programs, there are recruiting-type programs for civilians at varying levels. For example, there are internships for high school, junior college, trade school, and 4-year college students, as well as programs for recent graduates that DoD uses for workforce needs and in the face of staffing problems. Such programs are accredited and have strict guidelines (*DoDI 1400.25-V410*, U.S. DoD, 2013).

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3
Contexts for Effective Learning

The previous chapter focused on the pathways representing formal training and educational trajectories in the military context. However, learning in the military is not confined to the classroom or the training range. As this chapter will discuss, learning is increasingly taking place in a variety of spaces, but regardless of the precise context it is critical to consider the factors associated with these contexts that have the potential to shape learning effectiveness. Thus, the current chapter examines multiple learning contexts—learning environments such as classroom or online—and the opportunities to bolster effectiveness.

The chapter begins by reviewing basic learning principles and how to apply them to optimize instruction. However, as the committee noted in Chapter 1, this report has been careful not to replicate the two existing National Academies' reports on learning, as doing so is outside the scope of this report. The committee refers readers to those reports for a more thorough and detailed discussion of basic learning principles (National Academies, 2018a; National Research Council, 1999). The chapter discusses several key conditions and characteristics of effective learning environments, including instruction and learner autonomy. Next, the chapter articulates the dimensions of learning contexts and then reviews the importance of needs assessment, which helps determine the who and what of learning opportunities. Last, the chapter concludes by considering the research on maximizing effective team learning contexts.

OPTIMIZING INSTRUCTION AND TRAINING: PRINCIPLES AND CHALLENGES

Knowing how to enhance instruction, training, and self-directed learning has always been important in military contexts, but perhaps never more than now. The rapidly changing, complex nature of the modern world requires updating competencies and knowledge, whether as part of formal training on new equipment or procedures or as part of a given individual's personal aspirations and goals. In that sense, knowing how to optimize learning is critical during training and instruction—in the classroom and the field—over the course of one's military service.

Acquiring, Retaining, and Retrieving Critical Competencies

Learning occurs in three phases: acquisition, retention, and retrieval (Melton, 1963; Unsworth, 2019). A critical component of acquiring competencies is the relationship of the to-be-learned competency to what a given learner already knows (Thorndyke & Hayes-Roth, 1977; Brod, 2021). This relationship can be negative as well as positive, with the issue being the transfer of prior learning to new learning (Barnett & Ceci, 2002). Importantly, the ideas discussed here apply to learning about facts and events (e.g., semantic and episodic memory) and to learning motor and other skills to automation (e.g., procedural memory; National Academies, 2018). For example, baseball swings, golf swings, hockey swings, and tennis swings share components, so competencies in one of those sports can transfer positively to others, but there can be instances of negative transfer as well. The rotated position of a baseball bat at contact, for example, does not matter in the same way that the rotated position of a tennis racket or the face of a golf club matters.

Retention refers to whether the competencies demonstrated during the learning process by students or trainees are durable and remain stored, to be used at a later time. For a number of reasons, including the effects of recency, individuals who are able to execute competencies during the learning process can fail to retain that ability over time when that competency is needed in a real-world context. To demonstrate, a military learner attending Professional Military Education may be required to take a test for a given course. Studying the course material the night before the test day may be only mildly helpful in the short-term, because the material being studied is recently available. However, studies have demonstrated that this strategy is highly ineffective for retaining information over the long term. (Bjork et al., 2013; Schmidt & Bjork, 1992).

Retrieval is the act of successfully accessing the knowledge and competencies that are already stored in memory. Retrieval depends on the current context activating elements in an individual's knowledge store (Hintzman, 1986; Ratcliff, 1978; Tullis et al., 2014) and can involve the effortful recall of long-term memory (Polyn & Kahana, 2008; Unsworth, 2016; Unsworth & Engle, 2007; Unsworth et al., 2013). Retrieval is an imperfect process that is reconstructive and can be influenced by prior knowledge and experiences, expectations, and the current context. In other words, the very act of retrieving is often described as a "memory modifier" (Bjork, 1975). Importantly, retrieval is dependent on cues. To design effective learning environments, it is helpful to consider the competencies needed in specific operational environments as well as the potential cues present. In military contexts, for instance, many military learners are taught to fire guns in training. The conditions of warfare may be different from those of training, including the presence of emotional and other body-state cues that can be difficult to prepare for during training. Consequently, teaching military members to fire guns in training may not necessarily lead to their retrieval of these competencies during highly dynamic and stressful missions (Marshall, 1947).

Monitoring and Control Processes in Learning and Subsequent Access to Needed Competencies

Metacognition is defined as awareness of one's own knowledge and one's ability to understand, control, and regulate one's cognitive processes (Meichenbaum, 1985; 2017; Norman et al., 2019). Metacognition includes the monitoring and control processes that engage when a learner attempts to acquire new competencies (Bjork et al., 2013; Nelson & Narens, 1990). Metacognitive monitoring involves a subjective assessment of one's own cognitive processes and knowledge. Metacognitive control refers to the subsequent decisions, allocation of attention, and behaviors during the learning episode (Metcalfe, 2009).

During the acquisition stage, learners' control processes include decisions such as selecting what materials to study for more or less time and when they can stop studying some or all aspects of the to-be-learned material. These control processes are influenced heavily by monitoring processes, such as a learner's judgments of the ease or difficulty of learning a competency, for example, and whether the learner has mastered that competency (Bjork et al., 2013; Frazier et al., 2021). During retention, a learner may employ their control processes to practice retrieving that competency and associated control processes, such as whether to restudy or practice the competency. When the learner attempts to enact the competency, their control processes may include selecting a search process to find the memory, considering how to enact that competency, and when to end such a search. During retrieval, monitoring components can include whether a learner is confident in the accuracy of what they retrieved and whether what is retrieved is appropriate to the current situation, for example (Bjork et al., 2013). As future chapters will explore, military learners are facing and managing competing demands for their time. Emerging research has introduced considerations of how learners balance real-world constraints in dynamic environments, and how such constraints may impact behaviors related to monitoring and control processes (Hardy III et al., 2019; Neal et al., 2017).

Challenges Learners Confront in Monitoring and Control

It is of upmost importance to accurately assess whether military learners are ready for the complex situations they will face. For each of the following reasons, however, such an assessment is difficult and error-prone.

Misinterpreting Objective and Subjective Indices of Performance

When assessing whether someone has mastered a competency, one can observe the individual's performance, but only infer whether learning, measured by access to the needed competencies at some later time and context, has occurred. For example, information coming readily to mind during training may be a product of cues present during training that may not be present when that information is needed in some later real-world context (Rawson & Dunlosky, 2002; Karpicke, 2012).

Subjective impressions, such as the sense of ease or fluency when reading to-be-learned material, can mislead a learner as to whether they have achieved a level of acquisition and retention that will support access to critical competencies when needed later (Hertzog et al., 2003). For example, simply increasing the font size of the words to be remembered has been found to increase judgments of learning, presumably because the words were easier to read, even though this manipulation has little effect (Chang & Brainerd, 2022) or no effect (Rhodes & Castel, 2008) on actual memory. Similarly, rereading material can trigger a sense of fluency resulting from subconscious perceptual priming or shallow comprehension that does not reflect learning (Callender & McDaniel, 2009). Therefore, the ability to accurately monitor the current state of learning is better after a delay, because later retrieval accounts for a memory fading and, to some extent, for a change in context (Nelson & Dunlosky, 1991; Rhodes & Tauber, 2011; Thiede et al., 2003). For example, when learners write summaries after a delay, their accuracy in predicting how well they will perform on a later comprehension test is better than when they write summaries immediately after reading (Anderson & Thiede, 2008).

Instructors and learners can be prone to counterproductive beliefs about how adults learn and remember, which can lead to misinterpreting whether learning has occurred. Human memory, for example, does not work like a recording device that captures incoming information and replays it verbatim on command. Instead, the relationship and linkage of the to-be-learned material to what a given learner already knows governs what is stored in memory, and as previously mentioned, knowledge retrieval is often nonliteral and can modify memories (Koriat et al., 2000). One of the ways in which the retrieval process modifies memory is by strengthening the memory that is retrieved (Bjork, 1975; McDermott, 2021; Roediger III & Karpicke, 2006).

A learner's performance during instruction or training can be misleading, too. Conditions of training or instruction that make performance improve rapidly can fail to support long-term retention of critical competencies, whereas conditions that create a sense of difficulty and appear to slow acquisition can enhance retention in the long run (Bjork, 1994). For example, in a field experiment, college students studying physics engaged in either a class session where they followed along as instructors worked through problems in class through a lecture format (control condition) or students practiced identical problems themselves (experimental condition). Results showed that students in the lecture condition perceived greater learning than students who practiced problems in the experimental condition; however, students in the experimental condition actually learned more (Deslauriers et al., 2018). Thus, optimizing learning requires introducing certain difficulties and challenges for learners, but learners may not always perceive these difficulties as fruitful. As future sections in this chapter will discuss, learning takes time and best occurs in a psychologically safe, nonpunitive environment.

As described above, individuals can be vulnerable to illusions about how well they are learning. At the same time, research findings provide more insights than student intuition, and there is a large evidence base that defines the conditions and instructional practices that promote effective learning.

Distinguishing Between Learning and Performance

Research on differentiating between learning and performance has a long history (Soderstrom & Bjork, 2015; National Research Council, 1994). One theoretical framework treats this distinction as a function of two concepts: storage strength and retrieval strength (Bjork & Bjork, 1992; Kornell & Vaughn, 2016; Storm et al., 2012). Storage strength, which reflects true learning, is determined by how well associated a memory is with related knowledge; retrieval strength, on the other hand, reflects the momentary activation or accessibility of that memory.

Factors such as situational cues and recency of study or exposure heavily influence retrieval strength (Bjork & Bjork, 1992).

The storage and retrieval framework makes a few assumptions:

- That current performance is entirely a function of current retrieval strength, and storage strength acts to slow down forgetting and enhance retrieval strength;
- That storage strength of some competency, once accumulated, can become slowly weakened, but may never be fully lost. Retrieval strength is volatile and depends highly on both recency and the degree to which a competency is associated with the current situational cues; and
- That current storage strength enhances the gain or slows the loss of retrieval strength. However, perhaps less intuitively—the higher the current retrieval strength of a given competency, the less the gain in storage strength from retrieval or restudy. Similarly, the lower the current retrieval strength the higher the gain in storage strength.

The key implication here for military training is that conditions that most rapidly increase retrieval strength differ from the conditions that maximize the gain of storage strength. Assumptions that current performance reflects learning, as measured in a post-training context, can potentially result in selecting suboptimal learning conditions. For instance, these assumptions may result in instructors choosing less effective conditions of training, such as massed practice on a given competency, over more effective conditions, such as interleaving the practice of different competencies. In other words, if trainees or instructors misinterpret current retrieval strength as storage strength, they become susceptible to preferring poorer conditions of learning.

To illustrate, consider a Marine learning combat water survival during basic training (*MCO 1500.52D*, U.S. Marine Corps, 2010). During the rigorous Combat Water Survival Basic qualification, Marines master critical skills like treading water while maintaining control of their rifle, shedding full combat gear underwater, and transitioning between survival strokes. A Marine might easily demonstrate these skills during training and recall key principles immediately afterward—showing high retrieval strength. However, what is crucial for survival is maintaining this knowledge long-term. Storage strength is reflected in how well a Marine can recall and execute these vital skills months or years later, perhaps when unexpectedly plunging into water during a night operation. The difference between retrieval and storage strength becomes stark: while many Marines can perform perfectly during training (high retrieval), only those who developed deep storage strength will maintain those life-saving reflexes when they are truly needed.

Conditions of Learning That Create Desirable Difficulties

Desirable difficulties are defined as the specific conditions of training or practice that create a sense of challenge for learners. These desirable difficulties can create opportunities for durable and flexible learning—including how, when, where, and what they learn—as measured in a post-training context. These conditions include:

- Varying the conditions of learning, instead of keeping them constant and predictable (Hall et al., 1994; Shea & Morgan, 1979). There is considerable evidence that varying task conditions and contexts improves competency acquisition (Schmidt & Bjork, 1992), such as learning to track a target (Wulf & Schmidt, 1997) or pilot a drone remotely (Jiang et al., 2024);
- Interleaving, an instructional strategy that involves mixing different topics together during learning, in contrast to blocking, which groups instruction by a single topic before moving to the next (Brunmair & Richter, 2019; Kornell & Bjork, 2008; Rohrer, 2012);
- Spacing, rather than massing, study sessions on a given topic (Bahrick et al., 1993; Carpenter, 2022; Benjamin & Tullis, 2010; Cepeda et al., 2006; Cepeda et al., 2008);
- Using tests, rather than presentations, as learning tools (Carpenter, 2022; Kornell & Vaughn, 2016; McDermott, 2021; McDermott et al., 2014; Roediger III & Karpicke, 2006; Roediger III & Butler, 2011; Yang et al., 2021); and
- Providing multiple opportunities to master the material (Rawson & Dunlosky, 2022; Rawson et al., 2013; Rawson et al., 2018).

To illustrate several desirable difficulties in the military, consider chemical, biological, radiological, and nuclear training during Army Basic Combat Training. Soldiers first learn protective mask procedures in a classroom setting, practicing the 9-step process of donning a M50 protective mask. This training deliberately incorporates several desirable difficulties: varying conditions (moving from classroom demonstrations to outdoor practice to a chamber filled with tear gas), interleaving (mixing mask drills with other survival skills), and testing (soldiers enter the chamber with their masks on, perform specific tasks, and then remove their masks to experience tear gas firsthand). The training culminates in the confidence chamber exercise, where soldiers demonstrate mastery by successfully performing these skills in an environment with real tear gas, typically during week four or five of Basic Combat Training (see West Point's standard operating procedures for chemical, biological, radiological, and nuclear training, *DPTM-SOP-CBRN*, U.S. Department of the Army, 2018).

There are varying theories of the mechanisms through which difficulty improves learning (Carpenter, 2022; Chan et al., 2018; Kornell & Vaughn, 2016). For example, one theory for the advantages of retrieval practice is that the sheer effort of retrieval improves storage strength; consistent with this view, items are ultimately better learned when retrieval is more difficult (e.g., as measured by time to recall) (Pyc & Rawson, 2009), even when successful retrieval of the item is not actually achieved and the item is presented after the attempt at retrieval fails (Kornell et al., 2015). Another (not mutually exclusive) theory, the elaborative retrieval hypothesis, is that the effort at retrieval activates related information in the knowledge network so that when the item is retrieved (or presented), it is more integrated into the network (Carpenter, 2009, 2011). Finally, retrieval may help learners with monitoring, distinguishing between the material they know and the material they do not know, as suggested by the finding that unsuccessful retrieval can enhance the effectiveness of subsequent study opportunities (Arnold & McDermott, 2013).

Importantly, not all difficulties are desirable (Yue et al., 2013). Presenting text material in small or blurry font, for example, will create difficulty for the learner in decoding the text and draw attention away from processes needed for learning (Gao et al., 2012; Gao et al., 2011). In contrast, desirable difficulties that engender long-term retention are those that support deeper engagement with the meaning of the material when possible. The effectiveness of such desirable difficulties in improving learning is generally sustained throughout the lifespan (Bertsch et al., 2007; Carpenter et al., 2022; Maddox & Balota, 2015; Simone et al., 2013).

The Benefits of Desirable Difficulties in Learning from Text

Learning from text varies with the goals and abilities of the reader, as well as the quality of the text (Meyer & Rice, 1989), and desirable difficulties can improve learning from text. For example, longer delays between reading and rereading encourage a more integrated memory representation and promote retention (Rawson, 2012). Similarly, testing rather than rereading enhances long-term retention (Roediger III & Karpicke, 2006).

Desirable difficulties that encourage readers to construct situational representations lead to better monitoring accuracy—learners realize what they do not understand and can thus better control their learning processes (Prinz et al., 2020)—and in general, more robust learning. For example, retrieval practice with text promotes inferential reasoning (Butler, 2010; Pan & Rickard, 2018). Research has shown that re-exposure to material organized differently and presented in different contexts enhances readers' retention of the material and the ability to solve novel problems based on the material (Mannes & Kintsch, 1987).

Readers who are already knowledgeable about the topic at hand seem to benefit from coherence gaps in text, in which connections between points are not explicitly stated, presumably because this encourages them to do more inferential reasoning during learning (McNamara et al., 1996; McNamara, 2001; McNamara & Kintsch, 1996). However, low-knowledge readers do not benefit from such gaps, and instead show better learning when texts are more explicit in making connections. Readers who believe they will need to teach the material show better comprehension and memory of the material after a one-week delay relative to those who believe they will be tested (Guerrero & Wiley, 2021).

While learning from text in online environments relies on the same fundamental processes as traditional reading, it places additional demands on processes related to search, navigation, integration across multiple sources and different modalities, and evaluation of credibility (Goldman et al., 2012; List & Alexander, 2019). Learners can develop these competencies. For example, high school students in government classes who were provided instruction on how to critically evaluate online resources showed improved reasoning in a task of digital literacy relative to usual treatment controls (Wineburg et al., 2022).

CONDITIONS AND CHARACTERISTICS OF EFFECTIVE LEARNING ENVIRONMENTS

Principles of Effective Instruction

Researchers in learning sciences have linked the fundamental principles of learning to the design of effective instruction, and the evidence is clear on how to design learning environments to positively affect learning (Pashler et al., 2007). Although most of this research has been conducted with K–12 or college students, the principles of learning on which they are based are well-established regardless of learner characteristics (see Chapter 4 for specifics on adults).

A report from the National Center for Education Research, Institute of Education Sciences summarized seven principles of effective instruction based on its review and rated the strength of the published evidence as strong, moderate, or low (Pashler et al., 2007) (see Table 3-1). Specifically, strong evidence was found for using quizzes to promote learning, with particular emphasis on quizzes to introduce topics and for retrieval practice, particularly when they are spaced over time. Strong evidence was also found for the effectiveness of asking deep and explanatory questions that stimulate thought and encourage the elaboration of explanations. Moderate evidence was found for the effectiveness of spacing learning over time and interleaving learning material.

Even though little evidence was found for the effectiveness of helping students allocate their study time efficiently (see Table 3-1; Pashler et al., 2007), more recent research suggests that encouraging students to adopt certain learning strategies can facilitate student learning (Dunlosky et al., 2013). Specifically, encouraging students to use generative learning strategies—that is, those that elaborate on the material to be learned through self-explanation and interrogation—testing oneself on the material, and engaging in distributive and interleaved practice (as described in the previous section on desirable difficulties) will all lead to greater learning. By contrast, popular learning strategies—like highlighting and re-reading—tend to be easier for students and quite popular but are relatively less effective for learning. Instructors can facilitate the use of effective learning strategies by designing their instruction to include them (e.g., elaborating on content and self-testing) and by communicating about less effective learning strategies (Dunlosky et al., 2013).

Instructional design elements with moderate or strong evidence supporting their effectiveness are active and effortful, such as introducing desirable difficulties (Bjork, 1994; McDermott, 2021), and they produce more lasting learning than more passive approaches. These design elements are effective across the learning dimensions, whether formal or informal and whether self- or other-directed, which are each discussed in the upcoming sections.

TABLE 3-1 Principles of Effective Instruction Rated on the Strength of Published Evidence

Principles of Effective Instruction	Level of Evidence

1. Space learning over time. *Arrange to review key elements of course content after a delay of several weeks to several months after initial presentation.*	1. Moderate
2. Interleave worked example solutions with problem solving exercises. *Have learners alternate between reading already worked solutions and trying to solve problems on their own.*	2. Moderate
3. Combine graphics with verbal descriptions. *Combine graphical presentations (e.g., graphs, figures) that illustrate key processes and procedures with verbal descriptions.*	3. Moderate
4. Connect and integrate abstract and concrete representations of concepts. *Connect and integrate abstract representations of a concept with concrete representations of the same concept.*	4. Moderate
5. Use quizzing to promote learning. *Use quizzing with active retrieval of information at all phases of the learning process to exploit the ability of retrieval directly to facilitate long-lasting memory traces.* 5a. *Use pre-questions to introduce a new topic.* 5b. *Use quizzes to re-expose learners to key content*	5a. Low 5b. Strong
6. Help learners allocate study time efficiently. *Assist learners in identifying what material they know well, and what needs further study, by teaching learners how to judge what they have learned.* 6a. *Teach learners how to use delayed judgements of learning to identify content that needs further study.* 6b. *Use tests and quizzes to identify content that needs to be learned.*	6a. Low 6b. Low
7. Ask deep explanatory questions. *Use instructional prompts that encourage learners to pose and answer "deep level" questions on course material. These questions enable learners to respond with explanations and support deep understanding of taught material.*	7. Strong

SOURCE: Pashler et al. (2007).
NOTE: The seven principles in this table reflect the National Center for Education Research, Institute of Education Sciences panel's consensus on applicable principles from research on learning and memory.

Aligned with the success of effortful design elements, researchers have examined the importance of creating active-learning instructional environments (Bell et al., 2008; Hood Cattaneo, 2017). Active learning environments require learners to create their own understanding of the learning content through exploration and experimentation. For example, an active learning environment might require students to work on a complex and open-ended problem with a team of other learners. Active learning environments can be contrasted with more passive learning environments, such as lectures—where students tend to receive information rather than engage with it. Active learning environments incorporate many of the effective instructional design elements shown in Table 3-1, such as working through examples, answering deep exploratory questions, and connecting newly learned content to students' experiences (Bell & Kozlowski, 2009). Research has shown that active learning environments are effective in educational environments (e.g., Hernández-de-Menéndez et al., 2019). In a seminal meta-analysis on active learning, students in more passive learning environments were 1.5 times more likely to fail an undergraduate science, technology, engineering and mathematics course than those in active learning environments (Freeman et al., 2014). Meta-analytic research further supports the effectiveness of active learning environments in undergraduate humanities and social sciences courses (Kozanitis & Nenciovici, 2023).

Experiential learning, one type of active learning, creates an instructional framework around experiences and includes aiding self-reflection, generalizing the experience, and experimenting with recently acquired competencies in new situations. These experiences permit more than the transfer of information—they can also help students change the way they think about information in that instance and on future occasions (Burch et al., 2019; Kolb 1984). A meta-analysis examining a 43-year span of research on experiential learning found that learning outcomes were significantly higher in classes using experiential learning pedagogies compared to traditional learning environments (Burch et al., 2019).

The effective learning principles listed in Table 3-1—such as isolating and developing competencies, receiving immediate and informative feedback, and refining one's performance over time by integrating interleaved practice and understanding spacing effects—have also been extended to military learning contexts (Goldberg et al., 2018; Williams et al., 2008). Meta-analyses have found that these methods can explain a portion of the variance associated with expertise, although the significance depends on moderating factors such as the content being learned and the existing skill level of the learner. For instance, Platz and colleagues (2014) found that these strategies worked well for music learning; Macnamara et al. (2016) found that engaging in these types of learning strategies was related to learning in sports, but more for novices than for experts.

Learner control is another aspect of learning environments that is particularly relevant in self-directed learning. Learner control is defined as the extent to which a learner has the discretion to affect their learning environment (Brown et al., 2016). A framework of learner control developed by Landers and Reddock (2017) as a result of a systematic review of the literature includes three broad categories of control: instructional control (e.g., whether the learner has discretion to skip or add material to the to-be-learned content; whether they can change the pace of instruction), style control (e.g., whether the learner can control the format or layout of training content), and scheduling control (e.g., whether the learner can change the time and location of training). Learner control tends to be associated with learning content delivered via technology, given that technology-enhanced learning environments offer more opportunities for learner control across all three dimensions. However, learner control can be designed into in-person instruction by allowing students to exercise discretion regarding how they approach independent research projects, for example.

Research supports the idea that increased learner control—including the choice of what to study and how long to study—enhances learning (National Academies, 2018). For example, a laboratory study using a relatively simple visual coding and recall task found that providing learners with a choice of what to study activated brain networks that support memory relative to more passive learning environments (Voss et al., 2011). A meta-analysis of learner control in online training environments highlights some important caveats to the effectiveness of learner control and highlights future research needs (Landers & Reddock, 2017). Specifically, research tends to confound different elements of learner control (e.g., combining time and location control in one study and always including pacing control in research on online learning) such that it is impossible to isolate the effects of some elements of learner control. This study also found that learner control was effective for skills training (e.g., application of knowledge to solve a problem), but results were not as consistent for learning facts, rules, and procedures. Moreover, sequence control—where learners can alter the order in which content is presented—had the most consistent positive relationship with learning knowledge and skills and was also more universally liked by learners.

Research also suggests that learner control interacts with individual differences such that it benefits more able learners, those with more prior knowledge, while less able learners may struggle in more unstructured learning environments. For example, one study found that lower-ability military members, as defined by scores from the ASVAB, learned more in group-paced training environments, whereas higher-ability military members learned more when training was self-paced (Hagman & Rose, 1983). Together, these findings suggest that learner control can be effective, but it will be important to think about the content to be learned and the needs of the individual learner.

A common thread across all learning contexts in the military is the importance of training the military learner to deal with an unpredictable environment. Within volatile, uncertain, complex, and ambiguous environments, which Chapter 5 will discuss in greater detail, unpredicted incidents and failures will inevitably occur. When these accidents do occur, research points to several factors that increase the likelihood that there will be productive outcomes or "productive failure," which allows for learning based on attempts to solve a problem (Kapur, 2016). Research has shown, for example, that error-management training, defined as "active exploratory training with explicit instructions that encourage errors during training," improves competency-based training outcomes such as post-training transfer and within-training performance (Keith & Frese, 2008, p. 67). Error-management training tends to include unstructured learning environments that provide learners with opportunities to make mistakes along with cues for learners that making errors can benefit their learning. The cues provide emotional support and encouragement to the learner (Keith & Frese, 2008).

The effects of error-management training are more pronounced for post-training transfer, or learning transfers beyond competencies directly trained for, than they are for within-training performance (Keith & Frese, 2008). Research has also found that error-management training is more effective when applied to performance tasks that differ significantly in nature or complexity from the training exercises, rather than tasks that closely resemble the training scenarios (Keith & Frese, 2008). Error-management training is one training approach that recognizes the importance of emotion in learning, which has not typically been studied in adult learning contexts (Camacho-Morles et al., 2021; Jorgensen et al., 2021; Pekrun et al., 2002). See Box 3-1 for another example of how military learning technologies can help facilitate productive failure.

BOX 3-1

Productive Failure and the Role of Learning Technologies

Research demonstrates that productive failure while learning something new can have meaningful implications for long-term retention and subsequent performance (Keith & Frese, 2008). As immersive learning technology has improved, training for specific competencies or occupations with potentially high-risk outcomes can take place in safer contexts, such as in simulations. For example, learning how to fly a plane, perform medical intervention for a combat related-injury, or operate a submarine can all take place in simulated environments before experiencing the real thing. In these types of settings, immersive learning technology coupled with data-driven assessment and feedback support productive failure by giving learners the space to engage in experiential learning and to fail many times before performing the task in the field. Using these environments to critically analyze and thoughtfully consider one's experiences is essential for experiential learning, transforming failures into valuable learning opportunities. (Additional assets of learning technologies are discussed further in Chapter 6.)

Transferring Learned Competencies and the Durability of Learning

The idea of transfer is directly linked to the retrieval of learned information. Although there are many useful ways to operationalize the transfer of learned competencies (Barnett & Ceci, 2002; Goldstein & Ford, 2002), two relevant concerns related to transfer are maintaining competencies learned over a period of time and the extent to which learned competencies generalize to new tasks and contexts (Baldwin & Ford, 1988). Researchers have studied both individual and environmental factors as determinants of positive transfer (Ford et al., 2018). One important determinant of positive transfer is how well a competency has been learned in the first place (Ford et al., 2018; Schendel & Hagman, 1982). As such, designing training environments to include repetition (relatedly, refresher trainings in the military), overlearning (learning to the point of a skill becoming almost automatic), testing, and the general introduction of desirable difficulties will enhance retention and slow the decay of learned competencies, even when there are few opportunities for practice. One review of 13 studies on training soldiers to master tasks requiring psychomotor competencies and retaining those competencies in military environments found that increased repetition in training, incorporating testing in training, spaced versus massed practice, and increasing the variety of equipment practiced on during training enhanced retention (Hagman & Rose, 1983).

Environmental factors are central to positive transfer. Without opportunities to practice newly learned competencies in a performance environment, acquired competencies will decay over time (Ford et al., 2018). New research focusing on soft skills specifically demonstrates these patterns, such that environmental factors are impactful, and opportunities are needed for transfer (Hamzah et al., 2024; Laker & Powell, 2011). Competency decay, related to the idea of retention discussed earlier, is particularly problematic when learned competencies are critical but not consistently executed within a job. For example, emergency workers learn competencies such as intubation, but may have little opportunity to practice them in their daily work. In such cases, effective training may include opportunities to practice newly learned competencies through virtual or augmented reality to prevent competency decay. Periodic technology-enhanced practice can also improve performance and increase self-efficacy for using the competency (Rajeswaran et al., 2018).

Performance is also likely to be slow and error-prone in the early stages of competency acquisition (Ackerman, 1988). This means that workers will likely take longer and make more errors when they are newly trained than when they are able to execute well-learned routines. Moreover, new routines may not be well understood by coworkers and managers, who may not be tolerant of errors, delays, and the use of newly learned competencies. One meta-analysis found that coworker and manager support are important environmental determinants of positive transfer (Blume et al., 2010). This effect is particularly strong for supervisors who can influence the extent to which individual workers practice learned competencies on the job.

A study of graduates of various Air Force training programs examined three dimensions of opportunities to perform a task: breadth, or the opportunity to perform an array of trained competencies back on the job; activity, or the number of times the trainees used those competencies; and the type and complexity of the task. The results showed that differences in opportunities to use trained competencies on the job were related to supervisor attitudes about the trainees, such as whether they felt the trainees had career potential and were trustworthy, and the support the trainees perceived from supervisors and coworkers to use their new competencies (Ford et al., 1992). This study provides further evidence of the importance of supervisor support for positive transfer.

DIMENSIONS OF LEARNING CONTEXTS

The learning principles described above can be designed into a wide array of learning contexts. Learning contexts can be described along continua across three dimensions: informal/formal, other-directed/self-directed, and incidental/intentional (Cerasoli et al., 2014; Wolfson et al., 2018). In a military context, learning may occur in a formal setting, such as in Professional Military Education programming—such as the Marine Corps University's Expeditionary Warfare School[6]—or in an informal setting in the field. The context may be other-directed, such as following a formal curriculum, or self-directed, where military members identify their own deficiencies and seek opportunities to address those deficiencies. Learning may also be intentional, where members seek specific assignments or other learning opportunities to achieve a goal, or incidental or unplanned and spontaneous, such as in response to errors occurring in the field. Although learning contexts represent each of these dimensions, the dimensions themselves are independent in that knowing whether a learning context is formal or informal does not necessarily provide information about whether that context is self- or other-directed or whether the learning was intentional or incidental.

Formal training and learning opportunities offer the greatest amount of instructor control regarding the content and explicit nature of the learning focus. These environments tend to rely on explicit curriculum and can be considered hierarchical, where another person, such as an instructor, or technology, such as an intelligent tutoring system, controls the delivery of learning content. While formal training and education offer hierarchical control, research shows that a large portion of learning occurs outside formal training and development contexts (Bear et al., 2008). Informal learning represents learning that is largely unstructured, such as learning on the job (Marsick et al., 1999). Informal learning environments are often beneficial in that they are more flexible than many formal learning contexts. Informal field-based learning is defined as intentional, self-directed behavior aimed at learning new work-oriented and organizationally

[6] https://www.usmcu.edu/EWS/

valued content. This generally takes place outside of a formal learning program (Wolfson et al., 2018, p. 16). The study of informal field-based learning has recently increased in importance given the prevalence of informal learning (Bear et al., 2008) and the increased use of educational technology that will increase the prevalence of informal learning in military contexts (see Chapter 6).

Other-directed learning contexts offer more hierarchical control over the content and the timing of learning. In contrast, self-directed learning contexts (Clardy, 2000) tend to have greater flexibility in terms of the timing and content of the learning process. Because self-directed learning environments depend on a learner pursuing a learning goal on their own, the motivation of individual learners is critical, as is a learner's ability to self-regulate—to strategically plan, monitor, and control one's learning process to accomplish desired learning outcomes—and to manage distractions, focus attention, and persist in the learning activity (Beier & Kanfer, 2010; Sitzmann & Eby, 2011).

Although informal learning is typically associated with self-directed learning, and formal learning is typically associated with other-directed learning, it is important to consider formal, informal, self-directed, and other-directed learning as independent of each other. Two examples illustrate this point. First, massive open online courses provide formal, self-directed learning environments for those who choose to engage. Second, on-the-job learning, such as shadowing a co-worker, tends to be a relatively informal learning activity that is often other-directed (Beier et al., 2017). As Chapter 6 will discuss, technology is rapidly changing the nature of instructional environments and the availability of self-directed formal online learning opportunities by creating environments that include structured experiences with learning goals, syllabi, and structured instructional videos.

The incidental-to-intentional dimension reflects the sometimes unintentional and unplanned nature in which learning and development occur. Incidental learning—learning social competencies while working with others, for example, or learning new words while reading a textbook for a class assignment—may infuse learning opportunities in environments that may otherwise not be considered learning contexts, and thus offer great utility. Consequently, incidental learning removes hierarchical control over the content, approach, and even timing of the learning process. However, incidental learning requires a degree of serendipity and may occur as a by-product of a different activity (e.g., Katz-Navon et al., 2009; Tannenbaum &

Wolfson, 2022). Intentional or planned learning contexts are those that reflect learning environments in which learning goals, opportunities, or even curriculum may have been developed deliberately to meet a specific need. Intentional learning contexts are thus the focus of the current report.

SYSTEMATIC NEEDS ASSESSMENT: DETERMINING THE WHO AND THE WHAT OF LEARNING OPPORTUNITIES

There are many groups of learners in the military with many career paths; a broad range of what is to be learned in terms of competencies; and many types of learning contexts (see Chapter 2). Given these complexities, instructional designers would benefit from considering what needs to be learned and who needs to learn it. The following section highlights the importance of adopting a systematic needs assessment to align learning with job performance requirements and maximize effectiveness.

Needs Assessment in Military Training

Training needs assessment[7] is a comprehensive and systematic process that considers the organization's goals for the learning activity; the organization's learning climate; the requirements of the job or task in question; the competencies needed to execute the job or task in question; and whether the people with those jobs have the requisite competencies to execute the tasks (Ford 2021). At the end of a training needs assessment, instructional designers need to know how the learning activity fits within the organization's goals, what the learning objectives are, the specific content that needs to be trained, and the people to be targeted to receive the training. This information is then used to design learning environments and to design systems to evaluate the effectiveness of training. Learning environments designed as a result of a systematic needs assessment could be formal, such as in the classroom, or informal, such as through job shadowing, depending on the competencies that need to be learned.

A systematic needs assessment is central to many instructional systems design models and can take many forms (Ford, 2021). A popular instructional systems design approach in military contexts is the Analysis, Design, Development, Implementation, and Evaluation

[7] A detailed overview of training needs assessment is outside of the scope of this report and is available elsewhere (Ford, 2021).

(ADDIE) Model (Sink, 2014) (see Table 3-2), which each of the Services has adopted (Sink, 2014). Military instructional systems designers who develop technical training courses continue to be trained to follow the ADDIE model, in which student assessments, such as exams and performance-based tests, are developed before other course content to ensure alignment of the curricula with the stated learning objectives (U.S. Department of the Army, 350-70-14 2021; U.S. Department of the Navy, Naval Education and Training Command, NAVEDTRA 130B, 2009; U.S. Department of the Air Force, Secretary of the Air Force, DAFH 36-2675, 2022).

TABLE 3-2 Common Instructional Design Procedures Organized by ADDIE

	Analyze	*Design*	*Develop*	*Implement*	*Evaluate*
Concept	Identify the probable causes for a performance gap	Verify the desired performances and appropriate testing methods	Generate and validate the learning resources	Prepare the learning environment and engage the students	Assess the quality of the instructional products and processes, both before and after implementation
Common Procedures	1. Validate the performance gap 2. Determine instructional goals 3. Confirm the intended audience 4. Identify required resources 5. Determine potential delivery systems (including cost estimate) 6. Compose a project management plan	7. Conduct a task inventory 8. Compose performance objectives 9. Generate testing strategies 10. Calculate return on investment	11. Generate content 12. Select or develop supporting media 13. Develop guidance for the student 14. Develop guidance for the teacher 15. Conduct formative revisions 16. Conduct a Pilot Test	17. Prepare the teacher 18. Prepare the student	19. Determine evaluation criteria 20. Select evaluation tools 21. Conduct evaluations
	Analysis Summary	***Design Brief***	***Learning Resources***	***Implementation Strategy***	***Evaluation Plan***

SOURCE: Branch (2009).

An important benefit of systematic needs assessment, when used as part of instructional design, is that it can help ensure the successful implementation of training and development interventions. Similar to methods used in implementation science—which aims to enhance the effectiveness of translating research findings into real-world settings by examining the systemic facilitators and barriers to promoting the uptake of research (Soicher et al., 2021)—training needs assessment can address the feasibility, fidelity, and sustainability of proposed learning interventions. Questions about feasibility, fidelity, and sustainability also need to frame a systematic needs assessment. For example, how feasible is it to train interpersonal competencies in an online environment, how well can instructors deliver the content, and how long will the training be supported by the institution given shifts in strategies and priorities? Although there are parallels between systematic needs assessment and implementation science, they have not been considered in concert in the current literature.

Needs Assessment Could Inform Professional Military Education

As described in Chapter 2, Professional Military Education programs provide instruction for future work challenges that are not yet fully known. As such, rather than preparing military learners for specific technical tasks, Professional Military Education programs focus on more enduring competencies, such as leadership, communication, and strategic thinking, which can help individuals succeeded across a range of potential future situations (Ellinger & Posard, 2023). However, despite the military's widespread use of these programs, the evidence remains mixed as to whether Professional Military Education programs provide useful preparation for a military career (Hanser et al., 2021). For example, among Air Force officers who attended a full-time, 12-month, in-residence Professional Military Education program, approximately 15 to 20 percent indicated that the program provided them with little, if any, knowledge useful for their military career, and 25 to 30 percent indicated they made little or no use of the competencies they gained in their subsequent military assignment (Hanser et al., 2021). As such, Professional Military Education programs may benefit from a more systematic instructional design approach, such as the application of the ADDIE model.

Formal needs assessment has not typically been a part of the curriculum design process for Professional Military Education programs (Ellinger & Posard, 2023). When needs assessment has been conducted to inform Professional Military Education curricula, it has often been qualitative in nature and restricted to defining needs for specific roles, such as battalion or squadron commander, rather than all members of the same rank (Ausink et al., 2018; Stewart, 1992; Stewart & Hicks, 1987; Wolters et al., 2014). Although people and problem-solving competencies such as critical thinking and communication are generally more difficult to assess than content taught in technical training, systematic needs assessment to guide Professional Military Education curriculum development is still possible. Although every possible future situation and needed competency cannot always be predicted, systemic needs assessment is about using data-driven approaches to maximize the likelihood of effectiveness.

Potential Needs Assessment Methodologies to Inform Professional Military Education

Applying systematic needs assessment to inform Professional Military Education need not be onerous. To analyze learning needs on the organizational and unit level, relatively straightforward surveys could provide useful information to help ensure that Professional Military Education curricula align with learning needs at each rank, if administered enterprise-wide. One straightforward method is self-assessment. For example, after determining the competencies important for performance at one rank, programs could survey earlier ranks to determine the competencies in which the military members need instruction (Ford & Noe, 1987) or the extent to which military members believe they need additional experience practicing the competency in a permissive environment, relatively free of obstructions and interference (Alliger et al., 2013).

Surveys of instructors who have recent operational experience and interact directly with many students of the same rank could also identify learning needs. For example, in an Air Force study to identify soft competencies, enlisted instructors with prior experience judged what percentage of their recent graduates possessed each of 17 organizationally valued competencies "to the level that should be expected in their first assignment" (Barron & Rose, 2021, p.12). Results showed that instructors identified deficiencies in self-awareness, upward communication, speaking, decision-making, and problem-solving among recent graduates, suggesting enlistees would likely benefit from additional training or education to develop these competencies before reporting to their first job (Barron & Rose, 2021). When first-line supervisors provided their own judgments of first-term Airmen after a four-year enlistment, they identified the same five competencies as common areas of deficiency (Barron & Rose, 2021).

Army Talent Attributes as Common Language for Distinguishing Potential Learning Needs

The Army has recently developed a comprehensive, well-defined, and broadly applicable Talent Attribute Framework that provides a common language for identifying competencies Army personnel may need (Royston et al., 2022; Royston & Glerum, 2023). Although this framework was developed with the primary purpose of distinguishing the attributes needed in different Army jobs, many attributes in the framework are durable, in that they have broad applicability across jobs and are currently taught in some form in Professional Military

Education, such as team building, team planning, coordination, and conflict management (Royston et al., 2022; Royston et al., 2023).

The U.S. Army Research Institute for the Behavioral and Social Sciences has conducted large-scale surveys to identify talent attributes current military members view as most important for successful job performance at specific enlisted (E-5 to E-9) and officer (O-1 to O-5) ranks. Although the existing Army Talent Attribute Framework studies identify the most important interpersonal and communication competencies for performance at each rank (Royston & Amey, 2023), additional studies are needed to establish where deficiencies exist. For example, if active listening is listed as one of the most important interpersonal competencies for successful E-5 performance (Royston & Amey, 2023), it would be important to understand if individuals at the E-4 rank lack active listening skills before advancing to E-5. By identifying deficiencies, more focused training interventions can take place.

Needs assessment for Professional Military Education curricula development could leverage the Army Talent Attribute Framework, integrating needs assessment with competency modeling. For example, such analysis could be conducted through instructor or subject matter expert surveys. This could be as straightforward as eliciting ratings on the extent to which additional training or education on applicable Army Talent Attributes is needed for specific ranks (Ford & Noe, 1987). Alternatively, this could entail eliciting ratings of the level of proficiency on each competency that members of a given rank already possess (e.g., E-4s) and comparing this to the level of proficiency viewed as needed for the subsequent rank (e.g., E-5s). One simple approach is to define levels of proficiency (e.g., Basic, Intermediate, and Advanced) in generic terms that could apply to any competency (Alliger et al., 2013) (see Table 3-3). When used to assess the competencies of military aviators, such simple proficiency level scales have demonstrated appropriate inter-rater reliability and expected relationships with tenure or experience (see Alliger et al., 2013).

TABLE 3-3 Sample Levels of Proficiency

Basic	"Understands primary concepts and fundamental methods; is able to perform activity [*demonstrate competency*] at a foundational level"
Intermediate	"Understands main concepts and fundamental methods in some detail; performs activity above a basic level (e.g., could diagnose and solve

	some problems, could show someone with basic level competency how to improve)”
Advanced	“Understands concepts and methods in depth and detail; is able to perform activity at an expert level”

SOURCE: Adapted from Alliger et al. (2013).

Recently, the Air Force empirically developed and published (*AFH 36-2647*, U.S. Department of the Air Force, 2022) behaviorally anchored proficiency levels for each of 24 organizationally valued foundational competencies identified as important for successful performance across an Air Force career (see Barron & Rolwes, 2020 for description of scale development and validation process). Many of these competencies overlap with Army Talent Attributes. The Army could conduct similar studies at the level of Skills or Behaviors within the Army Talent Attribute Framework for greater specificity, such as developing separate behaviorally anchored scales for competencies nested under teamwork. Doing so could provide a greater level of detail in distinguishing areas in which members of a given rank may need preparation in Professional Military Education before promotion.

CAPABILITY, AWARENESS, MOTIVATION, OPPORTUNITY, AND SUPPORT FRAMEWORK

Most research on instructional design has focused on formal training environments. Recently, scholars have developed a broad approach for assessing training needs and readiness related to informal field-based learning. The Capability, Awareness, Motivation, Opportunity, and Support framework identifies the personal and situational readiness factors that facilitate individuals’ engagement in informal field-based learning behaviors, such as seeking feedback, self-reflection, and experimentation (Tannenbaum & Wolfson, 2022). When considering whether learning can occur in a given environment, it is important to consider both the individual’s readiness to engage in learning and the opportunities and support for learning as they serve a crucial role in influencing both whether individuals engage in learning and whether they benefit from it.

Personal Readiness to Learn

Capability, awareness, and motivation can all contribute to an individual's readiness to learn. While individual characteristics such as personality and propensity play key roles, personal readiness concerns whether individuals can maximize their learning opportunities, whether they are aware of what, where, and when to learn or not to learn, and whether they are ultimately motivated to engage in learning in the first place. Chapter 4 will discuss the role individual factors such as ability, personality, and motivation play in an individual's ability and readiness to learn.

Capability, Awareness, and Motivation

Capability refers to the individual competencies that allow individuals to maximize their learning opportunities. For instance, general mental ability positively relates to individuals' success in training. In addition to general mental ability, the ability to learn from errors (Katz-Navon et al., 2009), along with metacognitive and self-reflection competencies (Svensson et al., 2004), can be key in boosting individuals' learning.

Awareness, while useful in general training, can be particularly critical in less structured learning environments. Part of awareness captures the individual's self-awareness about potential knowledge gaps, whereas other components of awareness pertain to identifying learning opportunities, particularly regarding what needs to be learned, where, when, how, and at times even from whom (Tannenbaum & Wolfson, 2022).

Motivation represents the "willingness to find and engage in learning opportunities, to exert discretionary effort to seek opportunities, experiment, and ask for feedback" (Tannenbaum & Wolfson, 2022, p. 399). How effectively individuals engage in learning is in part explained by their motivational differences (Colquitt et al., 2000). Some of these factors are explained by individual predispositions such as learning goal orientation (Choi & Jacobs, 2011) or curiosity (Lohman, 2009). However, unlike personality, motivation to engage in learning waxes and wanes and can be driven by situational factors (Klein et al., 2006; Sitzmann et al., 2009). Furthermore, motivation can be greatly influenced by situational factors such as support, discussed below.

Learning Opportunities

Opportunities for learning capture whether the environment is suitable to engage in learning. These environmental conditions can be conceptualized along the four continua of *richness, slack, malleability,* and *appropriateness* (Tannenbaum & Wolfson, 2022). *Richness* captures whether the learning environment provides opportunities for all students to explore ideas, issues, and problems, and a given environment can range from being barren to rich. Learning-rich environments can facilitate learning. For example, higher levels of learning are more likely to result in environments that offer opportunities for job rotations, task variety, and greater levels of interdependence that allow for more informal learning opportunities (Cerasoli et al., 2018).

Slack refers to having more than enough resources, supplies, or equipment to meet minimum needs (March & Simon, 1958) and learning contexts can range from having no slack to having a great deal of slack. For example, slack could represent time, other personnel to learn from, or even coverage to allow deviation from assigned duties. Related to slack in time, research has found that limited time availability can constrain learning motivation in distance education (Hillesheim, 1998) and in-person instruction (Mathieu et al., 1992). The characteristics of a learner’s job can also influence and relate to the potential opportunities for learning. For example, one study found that seeking feedback and engaging in self-reflection can be beneficial in jobs with high time-pressure, but detrimental in low time-pressure jobs (Wolfson et al., 2019).

It is possible that in high time-pressure jobs, simply working harder may not be sufficient, and working smarter may be a more fruitful approach, which benefits from seeking input from others. Learning by observing others generally takes more time because of the participation of the learner and the willingness of a peer to be observed.

The concept of *malleability* reflects how changeable the environment is to create learning opportunities. A manager might, for example, be able to reassign work such that it creates opportunities to learn for employees. Malleability is similar to learner control, described above, in that it reflects learners’ autonomy over the learning process (Tannenbaum & Wolfson, 2022). Employees may, for instance, modify their own work environment in ways that create learning opportunities.

Finally, *appropriateness* represents whether learning is the desired or appropriate behavior in any given situation. For example, if learning distracts a worker from mission-critical behavior, then engaging in learning may have detrimental effects. Moreover, in situations where the consequences of errors are dire, the ability to perform a task—rather than learn that task—will be the goal (Tannenbaum & Wolfson, 2022). In this way, the appropriateness of learning in a given situation may be of particular concern in the military context. Although errors can be a critical source of learning in an after-action review or debrief (e.g., Metcalfe, 2017), it is important to consider the potential consequences of failure, and the appropriateness of having a learning goal in any given situation (Katz-Navon et al., 2009).

Support for Learning

Support for learning captures whether the environment supports an individual's learning endeavors. This support can vary in terms of its tangible and symbolic nature and can arise from the work environment, leader, peer, and overall organizational practices. The work environment can be an amalgamation of many factors such as the job characteristics and the culture and climate of the workplace. For example, research on an Air Force technical training program found that opportunities to perform a skill learned in training back on the job were related to supervisor attitudes regarding the learner (e.g., likeability, trust, and career potential) and support from co-workers and supervisors (Ford et al., 1992). In the military context, the work environment is likely to differ across various settings, such as between garrison (home installation) and deployment, in a formal institutional setting versus everyday interactions, and even across different organizational levels, such as tactical, operational, and strategic.

Psychological safety, a non-punitive climate that is safe for interpersonal risk-taking (Edmondson, 1999), represents a critical factor within the work environment. Psychologically unsafe environments inhibit learning and information sharing (Frazier et al., 2017). One study found, for example, that individuals who engaged in informal learning in psychologically safe climates improved their performance (Wolfson et al., 2018). By contrast, individuals who engaged in informal learning in psychologically unsafe climates saw decreases in their performance. Research has shown that organizations can best support psychological safety by fostering a climate that encourages productive discussions, facilitates problem prevention, and promotes shared goal achievement (Edmonson, Kramer, & Cook, 2004). This includes implementing and incentivizing behaviors that reinforce psychological safety, and ensuring leadership promotes a safety culture (Edmonson, Kramer, & Cook, 2004; Salas et al., 2020b).

Another critical consideration comes in the form of *leader support*. In addition to often having the authority to provide resources or formally sanction learning activities, leaders play a pivotal role in establishing a culture and climate that can be conducive to or inhibit learning. One study, for example, found that teams with leaders who foster a sense of empowerment and collaboration engage in more informal learning (Kukenberger et al., 2015). Leaders can also act as mentors or coaches (Vozenilek et al., 2004), and they have a unique position whereby they have substantial influence on their subordinates' attitudes (Dulebohn et al., 2012). Thus, it may be useful to support senior personnel in becoming better mentors to support both instructors and learners in their own development. Scholars have defined this influence as part of leader-member exchange. Leader-member exchange refers to the set of expectations that leaders set, the expectations for subordinates to fulfill them, and the upward influence on those expectations (Graen & Uhl-Bien, 1995).

Different leadership styles may influence downstream learning and performance. For example, one study focused on transformational leadership in the Israeli Defense Forces. Transformational leadership is a style that is defined by the leader's ability to influence their followers by elevating their follower's goals, as well as boosting their confidence (Dvir et al., 2002). Participants assigned to the transformational leadership training condition attended workshops that embodied the major tenets of transformational leadership theory in all workshop activities. The results of the study showed that transformational leadership training increased the development of direct followers as well as the performance of the follower's followers, including performance in the obstacle course (Dvir et al., 2002).

Like leader support, *peer support* can play a pivotal role in learning, as learning is often a social process (Bandura, 2006). Learning by observing and seeking feedback inherently involves others in the learning process (Wolfson et al., 2018). For example, coactive vicarious learning is a learning process that includes a model as well as a learner, in which they both share, jointly process, and work to understand the model's work experiences (Myers, 2018, 2021). In other instances, peer support works in tandem with learning opportunities, such as slack or willingness to provide slack. Research suggests that both peer and leader support are important for success in informal learning contexts. However, their importance may depend on individual characteristics—a focus on promotion, for example—and contextual characteristics, such as understaffed environments where peer support may be lacking (Wolfson et al., 2018).

Lastly, *organizational practices* capture the policies and conventions that an organization has in place that either promote or inhibit individuals' engagement in learning. One study found that when organizations provide employees with more formal training opportunities, those employees engage in greater levels of informal learning (Choi & Jacobs, 2011). This highlights the fact that such practices may serve a dual purpose of promoting formal learning and signaling the presence of a positive learning climate that allows for informal learning. Another study highlights a similar effect whereby making formal training available may signal to employees that their organization values employee development (Bednall & Sanders, 2017), particularly in the presence of strong human resource management systems that are clear, consistent, and well aligned between the human resource office and the organization. Finally, research found that recognizing individuals' efforts increased informal learning (Rowden, 2002).

Military Instructor Factors

Instructors are a central component of formal learning environments. A large body of research in civilian education settings (Bettinger et al., 2015; Brodaty & Gurgand, 2016; De Vlieger et al., 2018; López-Martín et al., 2023), as well as a large-scale study of one of the military service academies (Carrell & West, 2010), demonstrates that individual differences in instructor characteristics explain variability in student learning outcomes (De Vlieger et al., 2019; López-Martín et al., 2023; Nye et al., 2004). For example, an analysis of 10 years of learning outcomes at the U.S. Air Force Academy showed substantive differences in student achievement based on the instructor assigned for a given course (Carrell & West, 2010). Studies in which instructor competence was varied also demonstrate the importance of instructor characteristics on learning outcomes (Justis et al., 1978).

Military programs may have a mix of military and civilian faculty, though military members typically account for the majority of instructors in most training and education programs (Keller et al., 2013; Reedy et al., 2020; Straus et al., 2014). Military instructors often enter instructor duty with substantial practical knowledge of the content subject matter (Keller-Glaze et al., 2016). Because they have personal experience in the military and a shared lived experience with the learners, military instructors can foster trust with their students, particularly if they foster an approachable demeanor that can motivate students. Research has shown that shared experiences, based on a number of factors, can support a mentoring relationship (National Academies, 2019).

Comments from invited panelists at the committee meetings[8] suggested that in many military training and education programs, explicit programmatic attention was needed to develop instructors as mentors who connect classroom content to learners' individual roles in support of national defense. For example, one invited panelist articulated the importance of military instructors who help students "find their why" for the long-term: helping students to recognize the tremendous responsibility they will have as military members and understand the connection between what they are learning and the overall military mission. In sum, new military learners may need instructors to continually invest in them as mentors to bolster the learners' success (Cole, 2012; Johnson & Andersen, 2010). The unique aspects of military instructor-student mentoring may be worthy of further study to better understand instructor effectiveness and implications for longer-term outcomes for military members.

Although military instructors come with extensive military experience, many lack more formal education in pedagogy, defined as instruction on teaching (Keller et al., 2013; Keller-Glaze et al., 2016). Even among military instructors with college degrees, most are unlikely to have a background in education. Most have not received training or education in pedagogy or teaching techniques for adult learners prior to their teaching assignment (Keller et al., 2013; Keller-Glaze et al., 2016). Military members transitioning to an instructor role, however, typically receive at least a few weeks of basic instructor training before teaching, such as the 2-week Army Common Faculty Development Instructor Course (The Army University, n.d.). Research in educational contexts points to the importance of receiving training in pedagogy specifically for student outcomes (Darling-Hammond et al., 2005; Ferguson & Womack, 1993; Guyton & Farokhi, 1987; Qu & Becker, 2003). As such, the lack of prior educational background that is typical of military instructors is likely to hinder the effectiveness of training in the military context to at least some extent.

Moreover, military instructors typically serve on controlled tours of no more than three to four years, with instructor tours sometimes further shortened because of deployments, Professional Military Education requirements, or short-notice assignments to other military roles

[8] The committee heard from experts in publicly available panel sessions, who spoke about military training and education contexts. For more on this see Chapter 1.

(Keller et al., 2013; Reedy et al., 2020; Straus et al., 2014). As such, military instructors typically do not have the opportunity to continue to develop professionally as instructors over the course of many years to the same extent as civilian teachers or faculty with longer tenure. There are practical approaches, such as train-the-trainer, that might support novice instructors. There are also pedagogical approaches that might support them, such as the use of technology-enhanced instruction (see Chapter 6) or flipped classrooms that might involve, for instance, video instruction with experts as homework followed by in-class workshopping of ideas. Although there is research supporting the use of flipped classrooms for instruction (Akçayır & Akçayır, 2018), we know of no research that examines the flipped classroom with novice instructors. Rather, research in educational contexts suggests that years of experience teaching is positively related to student learning and achievement (see Burroughs et al., 2019 for review), particularly at the secondary level, and when instructors teach the same courses or grade levels each year (Pil & Leana, 2009; Rice, 2003; Rockoff, 2004). These findings have important implications for training effectiveness in the military context and could ideally inform military personnel policies for the length of instructor tours.

TEAMS, TEAMWORK, AND TEAM TRAINING

More than ever before, the military requires groups of individuals[9] to work together in teams to achieve operational missions. Consequently, the competencies for effective teamwork are critical targets of instruction. Team learning, much like individual learning, refers to the lasting transformation in the team's combined knowledge and expertise, stemming from the mutual experiences shared among its members (Ellis et al., 2003). Within team environments, individuals can acquire insights not only from their own experiences but also from those of their fellow teammates. Team training focuses on developing teamwork-related competencies and improving team processes and performance (Salas et al., 2008b). Through training, teams can enhance their decision-making abilities, enhance their performance under stress, and reduce errors (Salas et al., 2008a; Salas & Cannon-Bowers, 1997). In that respect, findings from research aimed at generating a nuanced understanding of the intricate dynamics of effective

[9] See Chapter 6 for a discussion on how advances in technology can increasingly enable autonomous agents, such as bomb-disposal robots, to serve as team members and not just as tools.

teamwork hold the key to achieving significant strides in areas such as efficiency, safety, and overall operational excellence (Salas et al., 2020a; Tannenbaum & Salas, 2020).

Coordinating mechanisms, including closed-loop communication, mutual trust, and shared mental models, play a critical role in effective team performance (Salas et al. 2005). Many varied technologies may help foster coordinating mechanisms among team members (see Chapter 6), yet regardless of the specific technology used, these mechanisms remain fundamental. They all contribute to teamwork competencies and overall team performance and need to be considered as essential components across all teams. Closed-loop communication has been defined as the transmission of information between the sender and receiver regardless of the communication medium (Salas et al., 2005). Closed-loop communication involves checking in with team members to confirm that each message was received and confirming with the sender that the received message aligns with the intended message (McIntyre & Salas, 1995).

Mutual trust—another important determinant of team performance related to psychological safety—has been defined in the context of team science as the collective belief that team members will fulfill their responsibilities and safeguard the well-being of their fellow team members (Salas et al., 2005). Finally, research has found that developing shared mental models—collective understanding of a team's task and member interactions—among the team is an important coordinating mechanism for team performance (Salas et al., 2005). Teams that develop and utilize shared mental models effectively foresee and predict the needs of other team members, recognize changes within or among the team and/or with the task, and effectively adapt their strategies as required (Cannon-Bowers et al., 1995; Mathieu et al., 2000).

Team Training

Similar to the definition of individual training, team training can be defined as the initiatives aimed at developing important competencies crucial for effective teamwork (Salas et al., 2015). Competencies on teams commonly include information sharing, cooperation, and the establishment of shared mental models (DeChurch & Mesmer-Magnus, 2010). Since team training is tailored based on task requirements, its structure may vary across different teams. Important for all team training, however, are three key components organized over the training period, beginning with what comes before a training, what happens during training, and what takes place after training (Salas et al., 2020a).

As with the development of any training, it is imperative to assess the need for training through a systematic needs assessment, which will help to evaluate individual, task, and organizational needs to identify gaps and establish clear training goals and objectives. Following a needs assessment, the next step is to determine the design and delivery of such training, as the choice of training delivery methods requires careful consideration according to each team's needs and demands. Another critical component involves implementing immediate and specific feedback, which cannot be overlooked during this phase (Lacerenza & Salas, 2014).

Research suggests that the leadership style adopted by the team's leader directly influences the development of learning within the team and the organization (Bucic et al., 2010). Both formal and emergent leaders play a role in shaping learning and performance (Tafvelin et al., 2019). Formal leaders can guide team learning during training sessions by creating a supportive environment, encouraging open communication, and using transformational leadership techniques to promote reflection and growth. Emergent leaders (i.e., those that set up within the team when the need arises) enhance the training process by fostering collaboration, driving efficiency, and helping their peers apply new knowledge and skills.

After training, the focus shifts to the evaluation and sustainability of learned knowledge and desired outcomes (Salas & Stagle, 2023). Evaluating a team training program serves as an indicator of its success. Research supports grounding the evaluation in theory, incorporating multiple measurement methods, and drawing upon the observations and feedback of experts. Involving experts is critical, as they possess a comprehensive understanding of the subject and hence can identify areas for improvement. In addition, team members who are motivated and who actively engage in the training process and derive meaning from their training experiences help contribute to the sustainability of training outcomes, which enhances team performance and other desired team outcomes (Edmondson, 2008).

Team training represents an investment with substantial potential benefits for teams and the organizations they serve (Morey et al., 2002). For example, a meta-analysis found that team training led consistently to enhanced outcomes in multidisciplinary health care teams (Hughes et al., 2016). Another meta-analysis of training across different industries suggests that the benefits of structured training extend beyond healthcare teams to a wide variety of teams in diverse domains (Arthur et al., 2003). These meta-analyses support broader adoption of team training and provide insights on how to make them more effective in a given context. Through team training, teams can foster a culture of collaboration, inclusivity, and enhanced competencies and team outcomes, which can aid in creating an environment conducive to optimal performance.

Team Performance

The conceptualization of team performance is a multilevel process, emerging as team members manage their individual and team-level taskwork and teamwork processes (Kozlowski & Klein, 2000). The interconnected set of affective and motivational states, behavioral processes, and cognitive states is known as the “ABCs of teamwork” (Bell et al., 2018). These components exhibit significant correlations and mutually influence each other in a repetitive manner over time. The ABCs of teamwork demonstrate robust associations with team effectiveness (LePine et al., 2008).

The interplay of the ABCs of teamwork not only forms the cornerstone of team effectiveness, but also lays the groundwork for understanding effective team dynamics, particularly when considering the important factor of task interdependence. Task interdependence is defined as the extent to which team members depend on one another to accomplish the task goals (Driskell et al., 2018). Task interdependence is an important moderator of team functioning, because of its importance in team processes during task execution (Driskell et al., 2018). While teamwork manifests in diverse forms, acknowledging, fostering, and overseeing interdependence is an element that elevates proficient individual performers into team players, irrespective of the task or scenario (Johnson & Bradshaw, 2021). Ultimately, refining and enhancing team constructs—collective elements or dimensions that influence the dynamics, performance, and effectiveness of a team—needs to be an ongoing process in response to evolving team needs (Chan, 2019; Kendall & Salas, 2004).

An example of successful team performance can be found in Operation Red Dawn, which demonstrated the effective integration of Task Force 121 (special operations forces) and the 4th Infantry Division (conventional forces) in the capture of Saddam Hussein. The operation’s success stemmed from an innovative collaboration, which emerged from a shared recognition that conventional approaches focusing on high-value targets were failing (Hougham, 2005; Lawton, 2016). The integration culminated in the operational phase, where approximately 600 personnel from both special operations and conventional forces executed a carefully orchestrated mission involving multiple search objectives and rapid adaptation to emerging intelligence. The operation demonstrates how task interdependence, when properly leveraged, can transform traditionally separate units into an effective team capable of achieving complex objectives that neither could accomplish alone.

After-Action Reviews

After-action reviews, which are also commonly referred to as debriefs, were introduced in the U.S. military in the 1970s (Keiser & Arthur, 2021). After-action reviews represent a process following a performance episode whereby individuals or teams engage in feedback, reflection, and discussion. In the military context specifically, an after-action review represents a "professional discussion of an event, focused on performance standards, that enables soldiers to discover for themselves what happened, why it happened, and how to sustain strengths and improve on weaknesses" (*Training Circular 25–20*, U.S. Department of the Army, 1993, p. 1). Researchers have found team debriefs or after-action reviews within (Darling et al., 2005) and outside the military context (Lacerenza et al., 2018) are effective at improving team performance (Keiser, 2024; Keiser & Arthur, 2021).

In an after-action review, individuals or teams revisit recent experiences to gain an improved understanding of what went well and what could be improved (Tannenbaum et al., 2013), consistent with studies showing the benefits of providing feedback (Tannenbaum & Cerasoli, 2013). Meta-analytic findings have shown that after-action reviews work better when the level of assessment (i.e., the team or the individual) is aligned. That is, when seeking to improve team performance, the review needs to focus on the team; when seeking to improve individual performance, it needs to focus on the individual (Keiser & Arthur, 2021). Furthermore, after-action reviews tend to be more effective when there is a developmental intent and a psychologically safe climate (Tannenbaum & Cerasoli, 2013). Studies have found that this technique improves performance (Tannenbaum & Cerasoli, 2013) and reduces burnout (Chen et al., 2018). Recent work has highlighted the critical role of technology, such as the use of video cameras and voice recordings of performance on a task in the after-action review process, and offers guidance on how to leverage technology strategically to facilitate existing challenges in after-action reviews (Keiser, 2024).

Empirically based guidelines for utilizing after-action reviews suggest several key strategies for effective implementation (Keiser & Arthur, 2022). First, after-action reviews need to be tailored to the task type (i.e., individual or team-based), and when they are team-based all members need to be present regardless of the focus of the specific task. Second, after-action reviews need to utilize objective review media (e.g., video recordings) when possible. Teams can use a self-directed approach with this objective review media, while expert facilitation is more beneficial for individuals. After-action reviews need to follow standard, highly structured protocols when used in military settings. Team-based after-action reviews generally need to be limited to 20 minutes.

Discussing both successes and failures during the review to maximize learning opportunities while focusing on real-time personal performance, rather than solely on canned (i.e., recorded) scenarios, is necessary. Additionally, it is essential to recognize the value of after-action reviews to facilitate reflection among participants, allowing them to analyze specific experiences and identify the underlying factors contributing to team performance. This approach can enhance the team's capability for future challenges, ultimately helping teams develop a more comprehensive understanding of their performance. Including a reaction phase, where participants share their immediate thoughts, feelings, and impressions about a recent performance episode, is discouraged, as this can divert attention from performance evaluation and undermine the effectiveness of after-action review. Additionally, after-action reviews are most effective for complex tasks that lack intrinsic feedback, and where practitioners can consider the implications of error consequences; by contrast, after-action reviews may be less effective when errors lead to significant repercussions. Finally, research suggests that the effectiveness of after-action reviews varies based on the chosen approach. The goal is to select an approach that aligns with the learning objectives and tasks to maximize benefits (Keiser & Arthur, 2022).

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4
Understanding Adult Learners: Cognition and Motivation through the Adult Lifespan

The purpose of this chapter is to review evidence related to how individual variation in cognitive skills, knowledge, dispositions, and motivation can shape the learning process, as well as how individuals change throughout the adult lifespan and how these changes may affect learning. Thus, the focus of this review is not only on how individual factors interact with principles of learning and motivation in ways that are applicable across the adult lifespan, but also on how adult development in cognition and motivational processes shapes learning. Before diving into this topic, the committee felt it important to discuss learning styles. The idea of learning styles, which is about differences in learning and has gained popularity in recent years, is not backed by scientific evidence at all.

THE MYTH OF LEARNING STYLES

There is a tendency among individuals to think they have a unique learning style, such as facilitated learning when material is presented in a visual or auditory modality, and some educators may also be tempted to categorize learners into different styles to help them tailor instruction. However, a series of experiments found a complete lack of support for this idea (Pashler et al., 2009; Rohrer & Pashler, 2012; Willingham et al., 2015). Individuals may often have preferences, and some of these preferences can sometimes be reliably measured (Massa & Mayer, 2006; Manolis et al., 2013); however, there is no evidence that instruction aligned with those preferences improves learning (Massa & Mayer, 2006; Pashler et al., 2009). Thus, the use of resources to craft instructional materials to learning styles is wasteful. Because focusing on funding instructional approaches that accommodate learning styles distracts from the creation of programs built on evidence-based principles of effective instructions, learning outcomes may be negatively impacted.

In fact, short of organic damage, the architecture of how people learn is the same across all individuals. Despite the common misconception that people at different ages or from different generations learn differently, the principles of learning generally apply across the lifespan and birth cohorts. This does not mean that anyone can learn anything. There are large differences across individuals in their capacity and efficiency to learn given their abilities, prior knowledge, motivation, personality traits, and other individual factors discussed in this chapter. For example, people may react differently to whether they succeed or fail at learning, which may affect future learning (Box 4-1). These factors contribute to an individual profile that defies categorization into a learning style. Although it can be challenging for an instructor or teacher to determine what level of difficulty is desirable for a given learner, the principles discussed in this and other chapters (e.g., engaging in deliberate practice, as discussed in Chapter 3) can provide a guide and will operate similarly regardless of learner.

BOX 4-1
How Attributions Affect Learning

People experience both success and failure as they learn new things, and how the individual interprets success and failure can have profound effects on the motivation to persist in learning (Weiner, 1985, 2010, 2012). A learner's explanation for what caused their performance is called an attribution. For example, a learner who performs poorly on an exam may attribute it to poor ability or to insufficient effort to study. In the former case, attributing failure to an enduring trait that cannot be changed is likely to reduce motivation to study in the future, because the poor performance reinforces the belief that ability is limited and implies that studying will be ineffective. In the latter case, the individual who acknowledges the capacity to learn but attributes the failure to a malleable factor over which there is personal control is more likely to persist (Molden & Dweck, 2006; Yeager & Dweck, 2012). Beliefs that capacities can improve through effort are said to constitute a "growth mindset," while beliefs that abilities are fixed and immutable capacities reflect an "entity mindset." Individuals with growth mindsets are more likely than those with entity mindsets to interpret engagement with a difficult task as a challenge that provides an opportunity for growth rather than a sign of limited ability, and are therefore more likely to persist when learning is difficult. While somewhat controversial (Burnette et al., 2023; Macnamara & Burgoyne, 2023), research has found that interventions to restructure beliefs so as to engender a growth mindset can increase achievement (Yeager et al., 2019), though this effect may be limited to students who are academically at-risk (Tipton et al., 2023). Other attributions that affect persistence include those related to stereotypes about race, gender, or age (Walton et al., 2015), as well as beliefs about learning styles when they do not match the instructional format (Pashler et al., 2009).

COGNITION, MOTIVATION, AND ADULT DEVELOPMENT

Contrary to the view that the individual is largely shaped during childhood, adulthood is a period of highly dynamic cognitive and behavioral development (Baltes, 1997; Baltes et al., 1999). Age-graded changes in the biological substrates of behavior, the accumulation of experience, and changing social roles create highly individualized patterns of development in cognition and motivation that affect learning. In addition, cognitive development in adulthood is multifaceted, and all areas of cognition do not develop in the same direction, with areas of growth, decline, and stability (Salthouse, 2019; Schaie, 1994; Spreng & Turner, 2019). Even when it is possible to define "normal" developmental trends, tremendous variability in developmental trajectories overlay these trends (Hertzog et al., 2008).

Lifespan developmental approaches provide a lens through which to consider changes in ability and motivation over time (Baltes et al., 1999). In contrast to life stage models that consider development as a function of discrete states (Erikson 1950; Super, 1953), a lifespan approach views development as continuous. In other words, normative patterns of growth and decline in cognitive and motivational functions generally show gradual change. When trajectories do show change, there can be considerable variability in the onset. For example, while processing speed can show linear declines beginning at age 20 to 30 years, change is typically more gradual in most other cognitive functions through the fifth and sixth decades, with more accelerated change after that (e.g., Hartshorne & Germine, 2015; Salthouse, 2019; Schaie, 1994). While much of the evidence on lifespan development resides in research with extreme group designs that compares adults in their 20s with adults over the age of 60, a substantial base of research does make use of continuously aged samples that allow the lifespan trajectories of development to be charted. Even though development is continuous, we roughly characterize age groups for convenience following the conventions in the literature (i.e., 18-39, young; 40-60, middle-aged; 60+, older).

Given the demographic of many military members (mean age = 28.5, 39.4% age 25 years or younger, 12.2% older than 40; *2022 Demographics*, U.S. DoD, 2022), the committee focused its review on such research to the extent possible and notes when relevant developmental data fall outside the age range of typical military members. Recent changes in military policy have increased the maximum age for enlistment, allowing more individuals to enter the military in their late 30s or early 40s (Nieberg, 2024; Roza, 2023; Ziezluewicz, 2022) and continue serving in uniform into their early 60s (Hadley, 2023; Roza, 2023; Toropin, 2023). Separate from policy changes regarding uniformed military members, the committee noted that DoD Civilians can be hired at any age and typically do not have a mandatory retirement age. As such, it is important to take an adult lifespan view of military learners. One important feature of lifespan development models is that one person at age 50 might more resemble a 70-year-old in terms of competencies and motivation, while another person at this same age may more resemble a 30-year-old (Hertzog et al., 2008). In the context of lifelong learning, this means that the skill, knowledge, and motivation profiles of learners at any given age will be diverse and idiosyncratic.

DIVERGENT TRAJECTORIES OF DEVELOPMENT FOR FLUID AND CRYSTALLIZED ABILITIES

An array of theories about abilities exists, but most relevant to adult learning is one that considers both crystallized and fluid abilities (Cattell, 1943, 1987; Horn & Cattell, 1987; Salthouse, 2010). Crystallized abilities comprise areas of knowledge acquired through experience, including that related to formal education. Crystallized abilities are so well encoded and overlearned as to be relatively unaffected by physiological assaults (Horn, 1968) and tend to show growth through young adulthood and midlife and preservation or growth into later adulthood (Salthouse, 2019; Schaie, 1994). Because the development of crystallized abilities depends heavily on experience, vocabulary and verbal skills tend to grow with sustained literacy practices (Stanovich et al., 1995), and crystallized knowledge in specific domains (e.g., history, science), are more likely to flourish in areas consistent with the individual's interests and personality, presumably because people are more likely to habitually engage over time with activities they enjoy or find fulfilling (Ackerman et al., 2001; Ackerman & Rolfhus, 1999). For example, people with stronger investigative interests (who enjoy thinking through problems) tend to know more about the sciences and technology, while those who find enjoyment in artistic activities know more about art (Ackerman, 2000; Ackerman et al., 2001).

Theoretically, developing crystallized abilities depends on an individual's investment of effort and attention over time (Ackerman, 1996; Cattell, 1987). As such, developing domain knowledge is highly individualized, idiosyncratic, and dependent on a person's interests, education, and experiences (Beier & Ackerman, 2001, 2003). For example, an individual is likely to show growth in knowledge as a consequence of activities related to their occupation or hobbies (Ackerman, 2000, 2008, 2023). Thus, interest is a prime motivational driver for the development of domain-specific knowledge (Hambrick et al., 2019). Unsurprisingly, individual differences in knowledge structures increase with age, given the idiosyncratic nature of experiences, education, hobbies, and occupations people are likely to have. Thus, assessments of such specialized knowledge call for more personalized evaluation methods.

Fluid ability, sometimes referred to as mechanics, encompasses the mental operations—including memory, attentional control, novel pattern recognition, and spatial processing—needed to adapt to novel circumstances, especially in situations that require rapid responses (Salthouse, 2019; Schaie, 1994). Fluid ability tends to show normative declines as a consequence of biological aging. While such declines are typical, with measurable effects as early as the beginning of the third or fourth decade of life, the changes are usually relatively subtle through midlife (Hartshorne & Germine, 2015; Rönnlund & Nilsson, 2006; Rönnlund et al., 2005; Salthouse, 2009). As with the development of crystallized ability, there are large individual differences in trajectories of fluid ability, with variability depending largely on health and fitness (Brady et al., 2005; Emery et al., 2012), providing a potential benefit to military members, who tend to prioritize fitness (Box 4-2).

Fluid ability, as with crystallized ability and knowledge, is not a single, cohesive entity. Rather, it is a constellation of cognitive skills engaged for performing across activities (Kovacs & Conway, 2016; Savi et al., 2019; van der Maas et al., 2006; van der Maas et al., 2017). Working memory—the capacity for holding information in mind while engaging the numerous mental operations used to control attention and work with that information—is a concept closely related to fluid ability. While not identical, measures of working memory, such as holding a set of numbers in mind while understanding a sentence (Conway et al., 2005), typically correlate highly with measures of fluid ability (Ackerman et al., 2005; Engle et al., 1999; Kane et al.,

2005) and are often predictive of learning and memory (Daneman & Carpenter, 1980; Daneman & Merikle, 1996; Draheim et al., 2022).

As with fluid ability, age-related declines in working memory are well replicated (Alloway & Alloway, 2013; Hale et al., 2011; Hartshorne & Germine, 2015; Salthouse & Babcock, 1991; Swanson, 2017; Wingfield et al., 1988). The general picture that emerges from this literature is that age-related declines are subtle into midlife (Hartshorne & Germine, 2015; Swanson, 2017). However, some studies suggest declines are roughly linear from young adulthood to older ages (Hale et al., 2011) and become larger as demands on working memory increase and when a task requires visual and spatial information relative to verbal information (Hale et al., 2011). For example, a visual working memory task requiring recall of the locations of items in an array after a short delay shows greater declines relative to a verbal task of recalling a string of digits after a comparable delay (Hale et al., 2011).

Another construct that is closely related to fluid ability and working memory is that of executive control (also called attentional control and executive attention), generally conceptualized as the ability to maintain focus on task-relevant information and to inhibit irrelevant information (Braver, 2012; Miyake et al., 2000; Hasher & Zacks, 1988). While measures of fluid ability, working memory, and executive control often show some intercorrelation, conceptualizations vary with respect to the cognitive architecture relating these three capacities (Baddeley, 2012; Burgoyne & Engle, 2020; Draheim et al., 2022; Rey-Mermet et al., 2019). Executive control shows notable growth through childhood and adolescence (Karr et al., 2024), and like fluid ability and working memory, declines through the adult lifespan (Cornelis et al., 2019; Karr et al., 2024).

We note that while age-related declines in fluid abilities and working memory through young adulthood (~early 20s to ~40s, the period of typical military service) can be measurable, they are relatively modest. For example, declines over this period are typically no more than a half standard deviation in visuospatial working memory (Hale et al., 2011; Swanson, 2017) or speed of processing (Salthouse, 2019), and declines are less for executive control (Hughes et al., 2018) and verbal working memory (Hale et al., 2011; Swanson, 2017).

BOX 4-2

Physical Activity and Healthy Cognition: A Leg Up in the Military

Research has demonstrated that exercise is associated with increased blood flow to the brain and greater brain volume, as well as higher levels of a protein critical to the growth of new neurons. As such, exercise helps mitigate age-related declines in the hippocampus, an area in the brain that plays an essential role in learning and memory (Colcombe et al., 2006; Erickson et al., 2011; Firth et al., 2018; Walsh et al., 2018). In the military context, maintaining physical fitness is critical for readiness (Knapik & East, 2014). Fitness has direct implications for successfully completing tasks during combat, preventing injury, and improving stamina (National Academies, 2018; U.S. Army, n.d.). In addition to conferring a physical advantage, engaging in routine physical exercise will likely yield a cognitive advantage for military members. This has important implications for all military members who are continuously learning over the course of their career.

SOURCE: US Army, n.d. Army Combat Fitness Test. Retrieved May 2024 from https://www.army.mil/acft/

Preservation and growth in crystallized ability and knowledge, and declines in fluid ability and working memory, have been replicated in both cross-sectional data, which compare people of different ages at the same time, and in longitudinal data, which follow the same people forward in time. For example, one study illustrates the divergent trajectories of cognitive aging using cross-sectional and longitudinal trends (Salthouse, 2019). It shows the decline of memory abilities, processing speed, and reasoning abilities, which can be considered components of, or highly related to, fluid ability, along with the growth and stability of vocabulary abilities, which are components of crystallized abilities, into older ages. The study does not show domain knowledge related to job performance, which likely also increases throughout the working years through work-related learning activities (Ackerman, 2014).

Declines appear to begin later and present as more moderate in longitudinal data relative to cross-sectional data (Rönnlund et al., 2005; Schaie, 1994; Singh-Manoux et al., 2012). This is due in part to the conflation of age and generational (or birth cohort) differences in cross-sectional designs. There is considerable evidence for advantages on measures of fluid intelligence (Schaie, 1994; Trahan et al., 2014) and attentional control (Andrzejewski et al., 2024) for more recent generations, and later cohorts have shown reduced within-person declines in cognitive performance relative to earlier cohorts (Hultsch et al., 1992), presumably because of advances across generations in health, medicine, education, and living conditions (Drewelies et al., 2019; Gerstorf et al., 2020). There is evidence that these positive trends may be recently weakening, or even reversing, but findings are inconsistent (Bratsberg & Rogeberg, 2018; Meisenberg & Lynn, 2023; Trahan et al., 2014). Declines with successive cohorts have primarily been demonstrated in European countries, but have also recently been reported in a U.S. sample (Dworak et al., 2023). Cognitive development can also be impacted by historical events (called "period effects"), such as the September 11, 2001 terrorist attack in the United States (Sacco et al., 2003; Clouston et al., 2022).

Midlife is often regarded as the optimal age for cognition. Individuals who have invested themselves in developing skills and domain knowledge will have acquired crystallized knowledge and expertise in selected domains (Ericsson, 2006), while declines in fluid abilities are minimal up to the sixth decade (Soederberg Miller & Lachman, 2000; Schaie, 1994). This is the period in the lifespan during which people reach peak skill level in decision making (Agarwal et al., 2009; Strough & Bruine de Bruin, 2020), creativity (Simonton, 1997), and career achievement (Ericsson, 2006; Salthouse, 2012). As people develop, they accumulate competencies and knowledge and can compensate for subtle declines in fluid abilities. However, midlife itself is not a period of stability. Based on longitudinal data over 12 years, one study showed growth in crystallized ability and declines in fluid ability, memory, and processing speed during midlife (Zimprich & Mascherek, 2010).

Individual Differences in Cognitive Development

Each person follows their own trajectory in terms of how their performance on cognitive tasks changes over time (McArdle et al., 2002; McArdle et al., 2004; McArdle & Prindle, 2008), and research on the sources of that variability and the factors that support healthy cognitive development in adulthood is robust. Over the last decade, the potential for improving cognition and intelligence more broadly through cognitive training, typically through technology-based gamified practice, has received considerable attention in the popular press and scientific literature. While individuals usually show improved performance in the training activities, there is no evidence that such decontextualized practice with mental skills, often called brain training, enhances the development of fluid abilities, academic performance, or work performance (Melby-Lervåg & Hulme, 2013; Melby-Lervåg et al., 2016; National Academies, 2017; Simons et al., 2016). Rather, individuals seem to improve narrowly on the skills they practice within the context in which they are practiced. That does not imply that intellectual capacity is immutable, however.

Among the most significant factors promoting favorable intellectual development in adulthood is engagement in formal education early in the lifespan (Ceci, 1991; Ceci & Williams, 1997; Lövdén et al., 2020). The causal mechanisms underlying the lifelong advantages of early-life education for adult cognition are not entirely understood, but there are prevailing explanations. Education early in life may establish a reserve in cognitive and brain structures so that cognitive functions are better maintained with age-related deterioration and environmental assaults (Stern, 2002, 2021). Another (not mutually exclusive) account is that education engenders opportunities for physical and intellectual engagement that continue to support cognitive health, skill development, and knowledge growth through adulthood (Fujishiro et al., 2019; Liu & Lachman, 2020).

How education is structured also matters. Even though the fruition of adult cognitive development is often taken to be high levels of specialized expertise in some domains, such as medicine or engineering, the most effective educational pathway to achieving that goal may not be an early focus within one's domain of specialist training. Instead, more generalist training that increasingly transitions into domain-specific specialization may optimize developing expertise. For example, world-class athletes in a specific sport typically have early training in an array of different sports relative to national-class competitors. Also, relative to national award winners, Nobel laureates typically have more early experiences in academics and work that are in areas other than the discipline in which they received their awards (Güllich et al., 2022). Generalist training may also contribute to developing critical reasoning skills. For example, college students who take more courses outside their major show larger gains over two years in a composite measure of logical reasoning on well- and ill-defined problems (Orona et al., 2023).

Even though education is a powerful force in shaping adult development, ongoing engagement in mentally stimulating activities, such as complex work, social interactions, and hobbies, may continue to shape cognition through the adult lifespan (Hertzog et al., 2008; Stine-Morrow & Manavbasi, 2022; Stine-Morrow, Worm, et al., 2022). Cross-sectional correlations between such forms of engagement and cognition are often found, which provides very weak evidence for a causal account. Somewhat stronger evidence is found in longitudinal data showing early-life enrichment to predict the level of—or change in—later cognition performance. At the same time, it is important to keep in mind that the isolation of causal influences in developmental research is rarely achieved with high levels of certainty.

Most adults invest at least some time—more typically, a great deal of time, in work activities that support their careers, so it is not surprising that cognitive development can be shaped by work. For example, longitudinal data from a sample of adults ages 16 to 65 at baseline showed a reciprocal relationship over 30 years between mental flexibility and substantively complex work that places demands on the individual for autonomy and self-directed problem solving in ill-defined situations (Schooler et al., 1999). Also, controlling for childhood IQ, a lifetime occupation of complex work with people, such as mentoring or negotiating, or with data has been found to predict fluid ability at age 70 (Smart et al., 2014). Even with statistical controls, it is possible that such findings to some extent reflect selection effects or the effects of some third variable (e.g., inherently healthier or more robust individuals may be more likely to both engage in complex work and to perform at higher levels on cognitive tests).

However, a number of "natural experiments" (in which historical events create opportunities for complex work that are outside of the control of the individual) have also provided evidence for the causal account. For example, Irish women who had a more extended period away from the workforce (because of laws over a 40-year period in the mid-20th century making it illegal for married women to work) showed cognitive declines after the age of 50 that were inversely related to the number of years they were able to work (Mosca & Wright, 2018). Also, individuals who were ages 60-64 at the turn of the century and living in countries with tax and pension policies that encouraged early retirement showed lower scores on cognitive tasks relative to those in countries with policies that did not (Rohwedder & Willis, 2010). Novelty—the degree to which a job requires learning new things, offers opportunities for exposure to new information, and depends less on routines—is another feature of work that may support intellectual growth. One study found that novelty in work predicts reduced cognitive declines over 14 years in later midlife (Staudinger et al., 2020). On the other hand, job complexity, novelty, and autonomy have been found to predict levels of fluid abilities, crystallized abilities, and processing speed in midlife, but not changes in cognition over the subsequent 20 years (Hülür et al., 2020).

There is evidence for the enhancement of cognitive skills exercised in everyday activities. For example, individuals become more adept at generating novel ideas quickly after participating in a program of creative problem solving (Stine-Morrow et al., 2014). They also show better scores on a working memory task after a period of engagement with leisure reading (Stine-Morrow et al., 2022) and better performance on a battery of visual and spatial tasks, such as distinguishing and remembering abstract shapes, after extended practice with jigsaw puzzles (Fissler et al., 2018). Research has also found that social engagement and positive social interactions support positive cognitive development through multiple pathways, including cognitive stimulation (Brown et al., 2016) and buffering the effects of stress (Seeman et al., 2011). In fact, social factors and activity engagement may be especially effective in boosting cognition among those with fewer years of formal education (Agrigoroaei & Lachman, 2011; Lachman et al., 2010), suggesting that social and intellectual engagement in adulthood may somewhat offset lack of exposure to or early-life neglect of educational experiences.

Much of the evidence related to the effects of mental stimulation on adult cognitive development relies on samples that are older than typical military members. However, such effects would be expected to show continuity through the adult lifespan.

Just as cognition may be shaped positively by enriched environments, adversity in early life, such as exposure to poverty or abuse, can also compromise cognitive development through adulthood (Manavbasi & Stine-Morrow, 2024). For example, poverty in childhood has been found to predict reduced executive control function among adolescents and young adults, effects that can be accounted for by stress exposure (Evans et al., 2009, 2021). Traumatic events in childhood, such as parental alcohol or drug abuse, and in early adulthood, such as abuse or combat experience, have been found to predict linear declines in executive function and memory over nine years during midlife (Lynch & Lachman, 2020). Controlling for socioeconomic status, the experience of childhood abuse predicts lower scores on measures of working memory and attention in midlife (Roberts et al., 2022).

Some forms of adversity, such as severe prenatal or infant undernutrition, seem to have a sensitive period where the effects on cognitive development through adulthood become difficult to reverse with favorable environments later (Andersen, 2022). Other forms of adversity may create chains of risk, in which early exposure increases the probability of exposure to other forms of adversity later. Chaotic childhood environments, for example, can lead to risky behaviors that reduce educational opportunities. However, exposure to adversity does not necessarily translate into poor developmental outcomes. Depending on the timing and severity of exposure, various factors can mitigate the effects of adversity (Luby et al., 2020), such as the availability of supportive adults (Lee et al., 2021).

Early-life adversity can positively shape adult cognition through personal growth (Joseph & Linley, 2006) and stress inoculation (Seery et al., 2013). For example, undergraduates with moderate levels of self-reported adversity during childhood showed a cardiovascular response to test taking indicating engagement with a challenge. Nevertheless, it is clear that people vary in the extent to which they maintain or recover their mental health following adverse events. Such resilience is probably not a trait or stable disposition, but a process of adaptation that is not yet well understood (Kalisch et al., 2017).

Importantly, there is evidence that individuals engaged in military service are more likely to have been exposed to adverse childhood experiences than those with no military service, an effect that is more pronounced in the volunteer era of military service relative to the draft era prior to 1973 (Brosnich et al., 2014). The potential for such early-life adversity may predispose military service members to deployment-related stressors (Iversen et al., 2007; Sareen et al., 2013). See Chapter 5 for a discussion of stress and learning in military contexts.

MOTIVATIONAL PROCESSES IN LEARNING

Motivation has been defined broadly as the direction, intensity, and persistence of effort directed toward a goal (Kanfer, 1990), and it is an important determinant of adult learning (Chung et al., 2022). The following section examines theories and research related to how motivation affects an individual's choice to engage in learning activities and the motivational processes that contribute to continuous engagement during a learning episode (Beier & Kanfer, 2010).

Expectancy-value models, which describe the relationship between a learner's expectation to succeed at a task in relation to the value of completing the task, are useful for understanding the choices people make to engage in goal-related activity. Researchers have examined an array of expectancy-value models (Kanfer, 1990), but typically, expectancy-value formulations include three components:

1. Consideration of the value a person places on an outcome associated with engaging in an activity such as a job assignment;

2. The belief that a person will receive a desired outcome, such as getting a new job assignment, if they meet a performance expectation, such as successfully mastering a skill relevant to the new job assignment; and
3. A person's expectancy that if they engage in that activity, such as taking a class to learn a new skill, they will succeed, which would mean mastering the skill.

The theory of planned behavior is another broad motivational theory that has been applied widely to goal choice (Ajzen, 1991). This formulation goes beyond expectancy-value models by including intended behaviors and recognition of subjective norms, which are perceived expectations of important others concerning the behavior. For example, a subjective norm that might influence a military member's engagement in Professional Military Education might be the perception that supervisors value the educational experiences for promotion. Research on expectancy-value and the theory of planned behavior in learning environments suggests that behavioral intentions (e.g., intentions to complete a semester) are the best predictors of engaging in educational or training opportunities, and expectancies and attitudes about the opportunities predict intentions (Armitage & Conner, 2001; Davis et al., 2002). There is less evidence for the value of subjective norms for engaging in learning activities. However, this research was not conducted in military environments, which may be more communal and hierarchical than other organizational environments (see Chapter 5). In any environment, examination of the influence of context on motivation should consider statistical modeling approaches, such as multi-level modeling (Raudenbush & Byrk, 2002), to account for environmental effects.

In addition to these broad models, motivational theories also describe the intrinsic or extrinsic nature of a person's goals. Intrinsic goals reflect activities a person is motivated to engage in because they have a personal interest in them; these can be contrasted with extrinsic or instrumental goals, which have an external reward or instrumental value associated with them (Deci & Ryan, 2014). Theoretically, intrinsic motivation has been considered a function of the extent to which an activity fulfills three fundamental and innate needs: the need for competence or feelings of efficacy, the need for autonomy or feeling personal control over a situation, and the need for relatedness or connecting with others (Deci & Ryan, 2014). Thus, the expected value of the learning opportunity will theoretically increase when it satisfies these needs by increasing feelings of efficacy, increasing the individual's sense of personal control, and providing additional opportunities to more effectively interact with others (Deci & Ryan, 2014). Early research on intrinsic and extrinsic motivation conducted with children described how providing an extrinsic reward can undermine intrinsic motives (Lepper et al., 1973). In the real world, particularly in work settings, activities tend to be associated with both intrinsic and extrinsic rewards, demonstrated by the fact that even people who love their work usually work for pay.

More recent formulations of motivation theory have addressed the tension between intrinsic and extrinsic motivation. In the means-ends fusion model, intrinsic motivation is a function of a perceived connection between an activity and the goal that activity serves (Fishbach & Woolley, 2022). When activities are strongly associated or even inseparable from their goals, intrinsic motivation is likely to be strong. However, since most work-related activities have elements of intrinsic and extrinsic motivation, aligning those elements within a goal is important to increase overall motivation rather than undermine it. For example, a soldier who is intrinsically motivated to engage in leadership activities may not experience a drop in motivation for leadership training if that training is aligned with a promotion, an extrinsic motivator.

In support of the means-ends fusion model, a study of over 10,000 military cadets studying at the U.S. Military Academy found that intrinsic and extrinsic motivation often exist together. Cadets who had low intrinsic motivations for military service, but high extrinsic motivations (e.g., promotion), were less likely to succeed in the military by making the commissioned officer ranks. In contrast, having high intrinsic motivations for military service led to increased success in the military overall, particularly when extrinsic motives were low (Wrzesniewski et al., 2014). Although additional research is required to completely understand the interplay between intrinsic and extrinsic motivation, this research suggests that when learning opportunities align extrinsic and intrinsic rewards, overall motivation to learn will increase (Bureau et al., 2022; Fishbach & Woolley, 2022; Pintrich, 2003).

Often, workplace learning is compulsory, which in general could undermine motivation to learn (Baldwin et al., 1991). Motivation for compulsory training or development activity is not universally low, however. For example, the compulsory nature of some training programs may communicate the importance of the training to employees and help employees set expectations for what they need to learn to succeed on the job (Tannenbaum et al., 1991)—success that can mean the difference between life and death in the military. However, an illusion of choice may reduce motivation for training if those choices are not honored. One study found that when organizations provided employees their choice of training but could not honor those choices, motivation for training fell significantly, and learning in training was negatively affected compared with employees who were never provided a choice in the first place (Baldwin, et al., 1991).

Regardless of whether learning and development activity is voluntary or compulsory, it is important to frame the activity such that learners can set expectations about what they will learn and how much time and effort they may expect to expend. This information will help learners set realistic expectations that can affect motivation for subsequent training, and improve self-efficacy for learning (Tannenbaum et al., 1993). Moreover, labels attached to training and development experiences (e.g., framing training as an opportunity, as remedial, or as advanced) can affect learner motivation (Martocchio, 1992; Quinones, 1995).

Once an individual has chosen to pursue a learning goal, motivational processes continue to support learning. During the learning episode, or goal striving, learners participate in specific goal-directed behavior, set more immediate learning goals, and monitor their progress. They can then evaluate goal progress and adjust their allocation of resources as they see fit in order to reach their goals. In other words, maintaining attentional focus on learning requires constant metacognitive monitoring, evaluating progress toward one's goal, and adjusting effort based on this evaluation (Diefendorff & Lord, 2008; Kanfer & Ackerman, 1989; see the discussion of metacognitive monitoring in Chapter 3).

Although the following discussion will not delve into the array of motivational theories, it does elaborate on self-efficacy, one of the most significant determinants of both goal choice and goal striving. Self-efficacy—one's perception of their ability to execute a specific task or action (Bandura, 1982)—is a significant determinant of the choice to engage in a training and development activity and for persisting in that activity in the face of obstacles (Chung et al., 2022).

MOTIVATIONAL THEORIES THROUGH ADULTHOOD

Motivational factors that affect learning can be stable over time and appear to be an individual trait. At the same time, motivation can shift through the adult lifespan as a consequence of physical changes associated with aging, changes in cognition, perceived changes in temporal horizon, and changing social roles. Just as with cognition, motivation can be shaped in part by contextual factors related to birth cohort and historical events; however, generational categories, such as Baby Boomer, Millennial, and Generation Z, do not have scientific grounding to characterize such effects (National Academies, 2020: Rudolph et al., 2021).While the previous section dealt with how motivational processes affect learning, the focus here is on how motivations themselves are learned and shaped with development. This section considers three prominent theories of how motivational processes change through the adult lifespan and what is known about the development of certain dispositional factors that affect motivation, such as personality and values.

Theoretical Perspectives

Lifespan developmental theories describe how motivation changes through the lifespan in ways that influence one's choice to engage in training and development activities and one's motivation to persist while engaging in training and development activities (Kanfer & Ackerman, 2004).

Selection, Optimization, and Compensation

According to the Selection, Optimization, and Compensation model, successful development depends increasingly on strategies of selection, optimization, and compensation with progression through the adult lifespan (Baltes et al., 1999). Selection refers to goal choice, which becomes more discriminating during adult development so as to align with desired outcomes (Cross & Markus, 1994; Riediger et al., 2006). Increased selectivity through adulthood is thought to be driven in part by both a tendency to allocate attention according to existing knowledge and expertise, as well as the availability of personal resources (e.g., time, energy, social networks) (Hess, 2014; Kanfer & Ackerman, 2004). Optimization refers to the allocation of resources to strive for the goals that have been selected. Together, these represent selective optimization, which constitutes a set of strategies for improving and maintaining skills.

For example, as military members progress through their careers, they will increasingly allocate their time and effort to occupation-specific activities—a form of selective optimization. Consider a military intelligence analyst who recognizes the growing importance of open-source intelligence in their field. They might selectively focus on developing advanced social media analysis skills while optimizing their learning by seeking specialized training in digital forensics and foreign language proficiency. Compensation, on the other hand, involves developing a new organization of skills to offset declines. For example, expert typists maintain their typing speed with age by looking farther ahead in the text to offset psychomotor slowing (Salthouse, 1984). Compensation becomes crucial as service members adapt to physical or operational changes. For instance, an experienced combat medic who finds their hand dexterity slightly declining might compensate by developing more efficient triage protocols and improving their ability to direct and supervise other medics in mass casualty situations, focusing on decision-making over direct care. They might also enhance their teaching and mentorship skills to better train junior medics. Generally, selective optimization and compensation are important strategies for developing, maintaining, and extending procedural knowledge throughout a military career.

The evidence is mixed as to whether the use of selection, optimization, and compensation strategies varies with age. For example, middle-aged adults have been reported to make greater use of these strategies than both younger and older adults, a pattern that has been explained in terms of the greater utility of these strategies with age combined with limitations in their expression with late-life declines in resources (Freund & Baltes, 2002). A meta-analysis examining the use of selection, optimization, and compensation strategies in the workplace found that older workers were relatively more likely to report using these strategies than younger workers, though the effect size was small (Moghimi et al., 2017). Consistent with this model, however, studies have also generated robust evidence that individuals who report greater use of selection, optimization, and compensation strategies report higher levels of well-being (Freund & Baltes, 1998, 2002). Selection, optimization, and compensation strategies have also been associated with self-reported job performance, job autonomy, job satisfaction, and job engagement in work contexts (Moghimi et al., 2017).

Motivational Theory of Lifespan Development

The motivational theory of lifespan development focuses on the regulation of goal choice and engagement to maintain autonomy over the adult lifespan (Heckhausen et al., 2019). A core assumption of this model is that individuals shape their own development through strategic selection of goals within the constraints of maturational processes and age-graded opportunities afforded by social institutions. Accordingly, heuristics for goal selection include timing goal pursuit so it aligns with age-related constraints, selecting and focusing on goals that complement one another, and entertaining multiple goals to allow for alternative goal pursuit when the path to another goal is blocked.

For numerous reasons, individuals do not always select goals according to these heuristics, but there are costs associated, for example, with pursuing goals at times that are not in sync with age, such as delaying education or changing careers in midlife, and pursuing goals that compete for time and energy. Thus, according to this theory, achievement and well-being depend on flexible goal pursuit, which can be a strength in adulthood. While younger adults may show strong assurance in their ability to accomplish their goals, they can be less likely than middle-aged or older adults to identify concrete steps toward achieving them (Cross & Markus, 1994). Relative to later in the lifespan, subjective well-being in young adulthood is more related to a growth orientation such as attaining goals, while later in life subjective well-being is more related to maintaining what one has achieved and preventing loss (Ebner et al., 2006).

In the military context, these lifespan development patterns manifest in distinct ways. Junior enlisted personnel (typically ages 18-24) often exhibit strong growth orientation, pursuing multiple training schools and skill certifications while focusing on advancement to Non-Commissioned Officer roles. Mid-career members (typically ages 25-35) typically face more complex goal management, balancing leadership development with technical expertise while considering re-enlistment decisions (see Chapter 2). They also have to weigh the timing of career-enhancing education, such as when to pursue advanced degrees or specialized training. Throughout these career stages, military members work to manage competing goals—for instance, deciding whether to focus on cyber security certifications that enhance both military performance and civilian marketability, or to pursue language training that primarily benefits their military role. Senior Non-Commissioned Officers (often over age 35) often shift their focus from personal growth to maintenance and knowledge transfer, emphasizing mentorship and institutional preservation. Military members frequently need to balance evening college courses toward a civilian degree against intensive military training opportunities. Because military careers are typically shorter than civilian professional careers, with most members retiring by their early 40s, members need to simultaneously prepare for a 'second career' while maintaining military performance standards (see Chapter 5). This compressed career timeline creates unique challenges for goal selection and pursuit.

Socioemotional Selectivity Theory

Socioemotional selectivity theory suggests that the quality of motivational processes changes during adulthood with the foreshortening of the time horizon (Carstensen, 2006, 2021;

Carstensen et al., 2006). In midlife and beyond, people increasingly recognize that they have more time behind them than ahead of them, and as a result people begin to prioritize goals related to social connectedness and emotional regulation over exploratory and information-acquisition goals related to preparing for the future (Brandtstädter et al., 2010).

There is a range of phenomena consistent with this view that social and emotional motives take priority into midlife and beyond. For example, the positivity effect—increased attention with age to positive information and avoidance of negative information—emerges in midlife (Hoehne & Zimprich, 2024; Reed et al., 2014). There is also considerable evidence that as people reach midlife and later adulthood, they prefer to spend time with people they are close to over those in peripheral social networks (Fredrickson & Carstensen, 1990; Fung & Carstensen, 2006). Midlife, in particular, is a time when goals for establishing the next generation take priority (Lodi-Smith et al., 2021; Peterson & Stewart, 1990). In addition, prosocial dispositions and activities (e.g., empathy, mentoring, public service) are likely to increase through the adult lifespan (Bailey et al., 2021; Hill et al., 2010; Hubbard et al., 2016; Mayr & Freund, 2020). Finally, there is evidence for a developmental shift in values, such that individualism within individualistic cultures weakens as collectivistic values increase (Fung, 2013; Fung et al., 2016).

Socioemotional selectivity theory has important implications for career development. For example, younger workers faced with an expansive occupational future time perspective will want to expand their knowledge and expertise. As a result, they will be more likely to engage in achievement-oriented goals, such as taking on stretch assignments, relative to more socioemotional goals, such as mentoring others. In contrast, older workers faced with a more abbreviated time perspective will desire the opportunity to nurture established relationships and will be more likely to select socioemotional goals, such as engaging in training to develop leadership or management skills (Kooij et al., 2011; Shavit et al., 2023). These shifts in goals may be one reason older workers usually have lower participation in training and development activities than younger workers (Kooij et al., 2014; Rudolph et al., 2018). Socioemotional selectivity theory is closely related to motivational theories outside of the aging context, which examine goals to expand versus refine existing knowledge based on gaps between what is known and what one needs to know (Hardy III et al., 2019), although empirical research supporting this theory is not yet well established.

Developing Dispositional Factors that Shape Motivation

Dispositional factors, such as personality traits and interests, self-efficacy, well-being, values, and attitudes, contribute to the motivation to learn. Here we focus on those theories and dispositions most related to motivation for learning. Such factors typically are stable over time, but some subtle changes may occur with adult development. Personality is a collection of distinctive traits that characterize typical patterns of acting and reacting in the world, including openness, conscientiousness, extraversion, agreeableness, and neuroticism. Personality traits become increasingly stable through childhood and adolescence, and largely show rank-order stability (i.e., the same relative position) from young adulthood to midlife (Bleidorn et al., 2022). At the same time, biological aging and shifts in social roles can drive subtle age-graded change in personality, the most significant of which may be decreases in openness to experience, extraversion, and neuroticism. In addition, conscientiousness shows steady increases from young adulthood through midlife, with some declines from mid- to late life.

Experience can gently shape personality. For example, young adult experiences of entering the work force can nurture the development of conscientious (Roberts et al., 2003). Because personality can be an important driver of how enthusiastically one engages in an activity, these traits can shape intellectual development (Ackerman et al., 2001; Ackerman & Rolfhus, 1999). There is considerable evidence for relationships between personality traits and intelligence, with the most robust predictors being openness, a positive predictor, and neuroticism, a negative predictor (Anglim et al., 2022). Research on the relationship between personality and learning outcomes is sparse, though considerable evidence links conscientiousness to academic achievement, goal setting, and the ability to monitor and control learning (Spielmann et al., 2022). More research on this topic is needed, as there are clear implications for personalized learning (e.g., less conscientious students may benefit from greater scaffolding) and for intervention (Jach et al., 2023). (For more on the unique experiences of military learners and their impact on learning, see Chapter 5.)

Interest in and preference for certain activities can be powerful motivators for learning (Hidi & Renninger, 2006; Murayama et al., 2019). Vocational interest theory holds that positive experiences will reinforce interests, and negative experiences will discourage further interest in a subject area (Holland, 1997). Similarly, positive and negative experiences influence one's view of how one fits in a subject area. Moreover, people tend to compare their skills in one subject area to their skills in another, such that they gravitate toward those areas in which they perform better relative to other areas. For instance, math and verbal abilities tend to be positively correlated with one another, implying that those who perform well in one domain will tend to perform well in the other (Marsh, 1990). If a person performs relatively better at a verbal test than a math test, they are more likely to develop interest and self-concept related to verbal abilities than math abilities. A meta-analysis of 426 effects showed that the differentiation in motivational beliefs usually happens around high school, as educational experiences become more specialized (Wan et al., 2021). Furthermore, this research points to the importance of positive educational experiences for motivation for continuous learning. Like personality traits, they are relatively stable over time, but are also shaped by (work) experiences and adult roles (Low & Rounds, 2007; Low et al., 2005; Roberts et al., 2003; Su, 2020).

Self-efficacy

Recall that self-efficacy represents a person's perception of their ability to execute a specific task or action (Bandura, 1982). Determinants of self-efficacy are prior mastery experiences within an area, vicarious experiences such as seeing a person succeed in that area (particularly when one can relate to that person), feedback from influential others about one's performance, and physiological responses such as excitement. As such, self-efficacy for learning will be a function of whether a person has successfully engaged in a learning activity in the past, whether they see others like them doing well in training or leading the training, whether they are receiving positive feedback while engaging in learning, and whether they are feeling excited rather than terrified about the development activity. Although there has been some debate in the literature about the effects of self-efficacy on performance, and although results tend to suggest that self-efficacy is more a function of past performance than a predictor of future performance (Sitzmann & Yeo, 2013), there is also ample evidence that self-efficacy predicts the choice to engage in learning activity and persistence during the learning activity (Chung et al., 2022).

Goal Orientation and Mindsets

Mindsets are attributions about the malleability of traits such as intelligence. People with entity or fixed mindsets believe traits are immutable and unchangeable, whereas those with growth mindsets believe that traits can be changed through effort (Dweck & Yeager, 2019; also see Box 4-1 above). Mindsets related to intelligence have been studied extensively in educational contexts, with research suggesting that a growth mindset is related to persistence in the face of challenges, particularly as related to interpreting effort related to learning as signaling growth and development and a willingness to learn after failure, as opposed to adopting a defensive posture to protect one's self-concept of intelligence. Further, research in laboratory and field settings suggests that interventions can effectively increase growth mindsets, although effects tend to be small (Dweck & Yeager, 2019). More recent reviews of the mindset literature are more controversial, suggesting that the effects may be a function of bias (Macnamara & Burgoyne, 2023), but a more nuanced analysis suggests that mindset interventions are effective, although they tend to be more effective for some students (i.e., students at risk) than they are universally (Burnette et al., 2023; Tipton et al., 2023).

Theoretically, mindsets affect the goals a person pursues in achievement settings, that is, their goal orientation (Dweck, 1986), although recent research suggests that the alignment between mindset and goal orientation is not always straightforward (Yu & McLellan, 2020). Learning-goal orientation is typically related to a growth mindset and represents a focus on developing competence. Those high in learning-goal orientation will be focused on expending effort to master content. By contrast, performance orientation is typically related to an entity or fixed mindset and represents a comparative or normative orientation. Those high in performance orientation tend to be focused on demonstrating competence and normative assessments of their performance. While a learning orientation would appear to be best for learning, given the focus on developing versus demonstrating competence, research on goal orientation tends to show mixed results, suggesting important moderators of the relationship between goal orientation and learning (Deshon & Gillespie, 2005). One reason for these mixed results is likely a function of the alignment between performance orientation's focus on demonstrating competence and the method for assessing learning in many educational environments, such as through exams, where demonstrating competence is necessary for success (Beier et al., 2010).

Research has examined knowledge development in a course through the assessment of both course exams and the organization of student knowledge (i.e., knowledge structures) compared to the instructor's knowledge structures during a semester-long course. Results of this study showed that mastery orientation was more highly related to the knowledge structure assessment than to exam performance, and they also found that performance orientation was more highly related to exam performance than to the knowledge structure assessment (Beier et al., 2010). Moreover, the importance of mastery or performance orientation may depend on task complexity and the stage of knowledge acquisition. Research suggests, for example, that performance orientation was positively related to learning outcomes when the task to be learned was relatively simple versus complex (Steele-Johnson et al., 2000). Others have found that having a high-performance orientation impeded performance at early stages of learning when learning novel tasks is most difficult (Seijts & Latham, 2001).

Grit

Grit has been defined as an individual-level trait that includes the combination of perseverance and passion for pursuing long-term goals. Importantly, it includes the maintenance of effort in the face of adversity, failure, or barriers (Duckworth et al., 2007). Although grit is highly related to conscientiousness, one of the Big Five dimensions of personality, there is some evidence that grit is associated with a variety of indicators of success above and beyond conscientious (Duckworth et al., 2007; Duckworth & Quinn, 2009). For example, a longitudinal study of over 11,000 U.S. Military Academy cadets found that while cognitive ability was more predictive of grades, only grit predicted completion of the highly demanding 6-week initiation training (Duckworth et al., 2019). Grit and physical ability were also predictive of cadets completing their bachelor’s degrees within four years. In the military context, specifically where academic and mission success include overcoming challenging and potentially life-threatening tasks, grit may be an important individual trait.

There are, however, noted psychometric and construct limitations associated with grit, particularly as related to its structure. Specifically, a meta-analysis of the relationship between grit and academic performance found that grit may be better represented by its individual components, perseverance and passion, rather than the higher-order grit construct, which combines these components (Credé et al., 2017). This critique calls into question the value of grit as a higher-order construct, particularly because it is so highly correlated with—and thus may be redundant with—existing measures of conscientiousness (Credé, 2018; Morell et al., 2021). In summary, the psychometric criticisms of grit suggest the need for more precise operationalization and assessments related to grit (Duckworth et al., 2021).

An overemphasis on grit has also been criticized because it tends to focus on the importance of individuals overcoming adversity rather than fixing the contextual factors that create that adversity in the first place (Schreiner, 2017). For example, even the “grittiest” military learner is required to adhere to the hierarchical military system that places limits on individuals' decision making (see Chapter 5 for more on this). Moreover, young adults from disadvantaged socioeconomic backgrounds may find that their schools' classrooms lack essential resources, a structural gap that no amount of individual passion and perseverance can necessarily overcome.

Well-being

People learn best when they have a sense of well-being (Boekaerts, 1993), which is shaped through the adult lifespan through both maturational and experiential forces. Emotional stability, the opposite of neuroticism, tends to increase through adulthood (Roberts, 2006). A recently published meta-analysis of subjective well-being based on international data from over 460,000 individuals across different generations suggested that life satisfaction generally increases from adolescence into young and middle adulthood (Buecker et al., 2023). Individual trajectories of subjective well-being, such as happiness, also vary with myriad factors (e.g., temperament, social relationships, cultural context; Pavot & Diener, 2004). Data from over 1,000 individuals enrolled in the Veterans Affairs Normative Aging Study suggested that depression and anxiety among veterans decreased from age 40 into midlife, a pattern similar to that among people in nonmilitary samples, but also increased in later life among those who had been exposed to combat (Lee et al., 2019). This effect may be attributable to multiple stressors (Lee et al., 2022).

Psychological well-being refers to the capacity to flourish and is characterized by self-acceptance, positive relationships with other people, autonomy, a sense of mastery and competence, a sense of purpose, and a sense of personal growth (Ryff, 1989, 2018; Ryff et al., 2016). Cross-sectional data suggest that autonomy, mastery, and positive relationships with others usually increase through young adulthood into midlife (Ryff, 1995). A sense of purpose and autonomy is significantly associated with subjective well-being among younger adults regardless of life pathway (Melendro et al., 2020). There is considerable evidence that having a sense of purpose that defines a meaningful life and provides a sense of direction supports health and cognition.

Values and Attitudes

Values are guiding principles that contribute to goal selection and persistence (Sagiv & Schwartz, 2022). Values are most likely to motivate behavior when they are both more central to the self and activated in the situation (Verplanken & Holland, 2002). Shaped by both biologically determined factors related to temperament and by socialization processes (Boer & Boehnke, 2016; Sagiv & Schwartz, 2022), values develop early in the lifespan and become increasingly stable through adolescence (Pöge, 2019). Values show considerable rank-order stability during adulthood (Milfont et al., 2016), but can be changed through significant life events or long-term changes in life circumstances. For example, the values of individuals immigrating to a different country can show subtle changes that are more aligned with their new home (Bardi et al., 2014).

Taxonomies of values can be very fine-grained, but there is some agreement that values can be characterized in terms of two broad superordinate categories: individualism or personal focus versus collectivism or social focus (Triandis, 1989, 2001; Triandis et al., 1988). Those with individualistic values prioritize personal goals over the goals of the group and are guided more by their own attitudes than by group norms. Individualistic values include self-enhancement (e.g., achievement, power) and an openness to change. Those with collectivist, or self-transcendent, values prioritize communal goals and maintaining relationships within the group. Collectivist values include benevolence and a general concern for the welfare of others. For example, a collectivist would be more likely to try to resolve conflict so as to preserve relationships through mediation, while an individualist would be more concerned with justice through the courts. During the COVID-19 pandemic, individuals living in regions in which people endorse more collectivist values were more likely to mask in social settings, relative to those living in areas where people endorsed more individualistic values (Lu et al., 2021). Consistent with the shift to social motivation posited by Socioemotional Selectivity Theory, there is evidence for a developmental shift toward more collectivist values through the adult lifespan (Fung, 2013; Fung et al., 2016).

The military culture emphasizes the importance of collectivism (see Chapter 5 for more) and, beginning in basic military training, formal military training and education programs often aim to instill core values such as teamwork and selfless service in individuals who may have held more individualistic values prior to entering the military. Also, as noted in Chapter 2, military training and education programs include curricula on both leadership and followership, consistent with military doctrine emphasizing that every military member has the duty to be both a leader and follower (e.g., *Army Leadership and the Profession,* U.S. Department of the Army, 2019). Values for self-enhancement versus self-transcendence may relate to the motivation to take on formal leadership roles in the military. The motivation to lead is multifaceted (Chan & Drasgow, 2001). Some individuals enjoy leading and see it as a core part of their identity (affective-identity); some feel it is an honor and also an obligation (social-normative); and others lead because of perceived personal benefit (calculative). In a military personnel sample enrolled in senior leadership courses (Clemmons III & Fields, 2011), those with high self-enhancement values scored higher on affective-identity and social-normative motives to lead, while those with more self-transcendent values were less motivated by these factors; rather, those with self-transcendence scored especially low on the calculative scale, suggesting that collectivistic values may engender engagement with leadership activities without consideration of personal rewards. Although nearly half of DoD civilians previously served as uniformed military members, those who lack prior uniformed military service are unlikely to have had the extended period of acculturation in collectivist values typical of enlisted personnel and officers, and the impact of this difference on motivation for learning is unclear.

Given the strong value system of the military and the importance of learning these values as part of military acculturation (see Chapter 2), an important concern for this report is whether and how military recruits might be taught values. As above, values are largely stable through adulthood but can also shift to be more consistent with movement to new cultural contexts. The mechanisms through which this occurs are not entirely clear. Some core military values, such as integrity and ethics, are also values that educators have been expected to instill as part of "character education" or "moral development" in K–12 schools (see Bebeau et al., 1999). However, researchers have noted the lack of systematic research to adequately distinguish among K–12 moral or character education interventions theoretically to appropriately evaluate effective strategies for designing interventions (Bebeau et al., 1999). A review of K–12 character education programs noted that many research reports on such programs "do not sufficiently elaborate on the content and pedagogical strategies of the program methods" and "most programs employ many strategies, and it is impossible to determine which ones account for the effectiveness of the programs because they have not been tested independently" (Berkowitz & Bier, 2005, p. 5).

A four-component model of moral processes supported by research (see Rest, 1986), has been suggested as a useful framework for future research to distinguish the effectiveness of moral education interventions. These components include (1) an awareness of how our actions affect other people, (2) judgment of actions as morally right or wrong, (3) prioritization of moral values (e.g., integrity) relative to other personal values (e.g., career achievement, affectional relationships, hedonistic pleasures), and (4) having the skills, courage, and persistence to follow through on moral action when faced with pressure or fatigue (Bebeau et al., 1999).

A closely related topic is attitude change. Attitudes, which are evaluations of an object, a person, or an abstract idea (Albarracin & Shavitt, 2018), are distinct from values and can be conceptualized as the expression of a value (Katz, 1960). As such values are more central to an individual's self-concept relative to attitudes, and thus more likely to be trans-situational. Attitudes do not exist in a vacuum but rather form a system of interdependent beliefs, and changing attitudes can depend on a number of contextual factors. For example, attitudes are more amenable to change when the changed attitude is already consistent with one's larger belief system or arguments are framed to link to existing values (Wolsko et al., 2016). Social context matters. For example, high-power communicators tend to use arguments related to competence, which are more convincing to high-power individuals such as a boss, while low-power communicators tend to use arguments appealing to social warmth, which are more convincing to low-power individuals such as an employee (Dubois et al., 2016). Other findings on attitude change, for example, highlight the effectiveness of strategies such as second-person self-talk, such as "You can do it!" or "Stay focused!" and the use of metaphors for changing attitudes about abstract or psychologically distant concepts (Albarracin & Shavitt, 2018).

Corresponsiveness Principle

Collectively, learning-related dispositions can show considerable development through the adult lifespan. However, such dispositions can also affect the experiences that individuals seek (Scarr & McCartney, 1983). This principle, that people select into environments according to their existing dispositions that in turn shape development to reinforce those traits, is called corresponsiveness (Caspi et al., 2005). For example, in a longitudinal study in New Zealand of young adults' development in the workplace, individuals with jobs at age 18 that require the mobilization of resources and management of personnel showed higher levels of agency at age 26 (Bardi et al., 2014; Roberts et al., 2003). Research has found partial support for corresponsiveness in a military context as well. In a large longitudinal study in Germany, where young men are automatically drafted into the military after high school unless they conscientiously object and select civilian community service, those who selected into military service were less agreeable, less open to new experiences, and less neurotic relative to those who selected civilian service (Jackson et al., 2012). Over the subsequent two years, the sample showed the typical patterns associated with maturity, including increased agreeableness and conscientiousness and decreased neuroticism. However, those who chose military service showed less growth in agreeableness, a difference magnified over the subsequent four years.

Life Stages

A lifespan perspective accounts for continuous change in the multiple facets of cognition and motivation, and though there are no well-defined demarcations among childhood, young adulthood, middle-age, and older adulthood, for example, it is possible to provide a general characterization of life stages. The following discussion focuses on emerging adulthood and middle adulthood as the stages most relevant to life in the military.

Emerging Adulthood

Emerging adulthood—late teens through mid- to late-20s—is the developmental period between being a child and being an adult (Arnett, 2000; Arnett et al., 2014). It is during this period that many military learners are at the beginning of their career and are in the process of recruitment. As discussed earlier, this is the life stage offering the most flexibility for peak physical conditioning and heightened capacity for fluid abilities, while at the same time characterized by more limited experience to support the development of competencies. This is also a time when people invest in self-focus and identity exploration. Characterized overall by instability and change relative to other periods in the lifespan, emerging adulthood can be a period during which the probability of risky behavior peaks. A key concern during this period is developing a sense of one’s purpose in life, a developmental task generally met with a sense of optimism for the future. In addition, given the importance of emerging adulthood for identity exploration, it is a period during which interventions promoting mental and physical health may have far reaching implications.

There is considerable evidence of increasing stability in interests and personality through this period (Low & Rounds, 2007; Low et al., 2005; Pusch et al., 2019). Developing purpose during emerging adulthood can have consequences for development at later life stages. For example, studies have found that prosocial purpose among college seniors predicts self-reported generativity, personal growth, and integrity about 13 years later (Hill et al., 2010). Similarly, identity resolution at age 20 shows some stability into midlife, predicting life satisfaction at that point (Sneed et al., 2012). However, those with low levels of identity resolution also show differential increases over time, with consequences for generativity and integrity in midlife (Mitchell et al., 2021). Collectively, there is evidence that emerging adulthood is a dynamic period of exploration that sets the stage for taking on adult roles through the stable development of identity, purpose, and vocational interests.

Middle Adulthood

Midlife has been called the rush hour of life (Knecht & Freund, 2016, p. 297), when people manage multiple roles and responsibilities across different domains. Relative to other life periods, midlife is understudied, even though it is arguably pivotal in the life course at both individual and societal levels (Infurna et al., 2020). For the individual, midlife affords increasing opportunities to capitalize on the knowledge and experience garnered earlier in the lifespan. Across society, roles central to leadership and mentorship of the younger generation and caregiving roles for the older generation largely fall to those in midlife. Concerns at this life stage with generativity combined with the acquisition of expertise make this a prime time for effective and satisfying mentoring (Lodi-Smith et al., 2021). Those in midlife contribute importantly to the well-being and success of the generations ahead of and behind them. Perhaps, counterintuitively, midlife is not a time of heightened stress, and self-reports of stress and stress reactivity decline with age from young to middle adulthood (Almeida et al., 2023). Thus, skills in emotion regulation developed during midlife may enable adults to cope with role strain (Charles, 2010).

STABILITY AND CHANGE IN LEARNING NEW THINGS THROUGH THE ADULT LIFESPAN

Given the discussions above, what are the implications of these changes in cognition and motivation for learning new things? Fluid and crystallized abilities, as well as domain-specific knowledge, contribute to the ability to learn new things (Beier & Ackerman, 2005). Remember, however, that the distinction between fluid and crystallized ability is theoretical, and authentic cognitive demands in the ecology of everyday life will depend on both, depending on the balance of novel task elements, context, and task demands relative to the existing skills of the individual. Furthermore, the development of motivational processes with maturity in adulthood can support learning effectiveness.

Theories of skill acquisition highlight the stages of learning and their ability correlates (Ackerman, 1988; Anderson, 1982). At early stages of the learning process, for example, the competencies to be learned are novel, so learning requires focused attention and effortful processing. As such, at early stages of learning novel tasks, fluid abilities can be the most important determinants of learning. As one acquires knowledge or skills, the learner enters the knowledge compilation phase in which learning is relatively less effortful. At this stage, fluid abilities are still important, but more domain-specific abilities that are similar or related to the skill being learned become important determinants of learning. For example, psychomotor abilities and fluid abilities will be important determinants of successfully learning to type at the knowledge compilation stage (Ackerman, 1988), and prior knowledge about general health along with fluid abilities will be important determinants of learning about how to administer cardiopulmonary resuscitation (CPR) (Beier & Ackerman, 2005).

Similarly, assembling a particular piece of equipment for the first time is likely to depend more on fluid abilities to understand the relationships among components and the mapping between instructions and actual assembly procedures, especially if the individual has little experience with assembly activities in general. As the individual gains more experience assembling the piece of equipment or similar pieces of equipment and develops skills to identify and distinguish among components and conceptual spatial relationships among the components that fit together, for example, the more an accurate and efficient assembly will depend on knowledge and the less it will depend on fluid abilities.

In general, people are more efficient in learning new information related to existing knowledge, but the accumulation of competencies through adulthood exaggerates this effect (Beier & Ackerman, 2005; Milburn et al., 2023; Soederberg Miller & Stine-Morrow, 1998). While individuals with high levels of crystallized verbal ability typically show a general advantage in comprehending and learning from text (Hartley, 1988; Johnson, 2003; Meyer & Rice, 1989; Rice & Meyer, 1986; Schroeder, 2011; Zelinski et al., 1993), content knowledge related to the text confers distinct advantages in selecting the meanings of words in context, making inferences, and comprehending the mental model of situations or events described by the text (McCarthy & McNamara, 2021; Noordman & Vonk, 1992; Noordman et al., 1992; O'Reilly et al., 2019; Wiley et al., 2018). Knowledge also tends to correlate with interest (Ackerman et al., 2001), which at least partially explains why middle-aged and older adults prefer routes to learning that depend on existing knowledge (Ackerman & Kanfer, 2020; Radvansky et al., 2001); that is, as people develop expertise it becomes increasingly effortful to pursue learning in completely new directions. Collectively, mature adults have an advantage in learning in domains in which they already have some knowledge and experience, both because cognitive processing is more efficient and because people are motivated to orient attention to things they find interesting. Thus, cognitive and motivational processes interact to support learning among mature adults.

Despite replicable declines in fluid ability and working memory, there is no evidence that aging compromises work performance (Beier et al., 2022; Ng & Feldman, 2008). There are likely many reasons for this, including the important role that knowledge plays in effective work performance (Ackerman & Kanfer, 2020), motivational processes that engender selective optimization to support deeper levels of expertise (Beier, 2022; Weigl et al., 2014), and the way knowledge-based compensation can offset any effects of age-related declines in speed or fluid abilities (Lövdén et al., 2010; Salthouse, 1984).

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5
The Military Learner

The previous chapters in this report examined the various factors associated with learning contexts as well as the fundamental principles of learning and developmental changes over time in the adult learner. While discussions about learning contexts and adult learners are important to consider independently, learning is informed by the intersection of person and context (National Academies, 2018a). Furthermore, this report has articulated the ways in which adults—and to some extent, contexts—are dynamic and can change over time. Therefore, the importance of this intersection is relevant not only at the beginning of a military career but over the entire duration of one's time in the military. The committee believed that it needed to examine the *person* in the military context to completely address the statement of task, particularly to address the questions on motivation and understanding how contextual and equity factors shape the effectiveness of training policies and practices. This chapter bridges the science of adult learners to the military context to better understand the military learner.

First, this chapter explores how the military learning environment aims to prepare personnel for complex multi-domain operations, where they may encounter stressful situations requiring swift decision-making in response to emerging challenges. Next, it describes the potential equity factors affecting military learners. Third, it describes the military learning environment as one in which military learners often have limited autonomy and are required to operate within a high power-distance culture, where power-distance is the extent to which less powerful individuals know and expect that power is distributed in ways that are unequal (Daniels et al., 2014; Hofstede 1980; 1981). Finally, it explains that certain motivations of military members affecting learning may be particularly salient at specific times in the military career. In this section, the committee starts with a discussion of military recruitment and then moves chronologically to examine the decisions on retention or separation after a recruit's initial service commitment. For those who plan to continue in the military, retention requires promotions and allows for advancement toward military retirement. These periods provide an organizing framework for this discussion.

PREPARING FOR EVOLVING AND STRESSFUL ENVIRONMENTS

A unique influence on learning in military contexts is the extreme environment militaries operate within, typically marked by its austerity, lethality, complexity, and moral intensity, which can impose distinct contingencies and causations on the learning process (Hannah & Sowden, 2013). These conditions, and lessons on learning within them, also apply to several other occupations such as those of police officers, emergency room doctors, border patrol agents, and intelligence officers, but unique to the military are the combat operating environments the forces operate in. Military learners train for and learn to provide multiple services, from disaster relief to rebuilding civilian infrastructures, but ultimately their primary purpose is to support national security and project or employ lethal force in defense of their nation's people, rights, or interests (Hannah & Sowden, 2013). As the following section discusses, these extreme and high-stakes environments, both for the military and for similar occupations, are constantly evolving and becoming increasingly complex. In addition to these changing conditions, military learners are expected to manage stress, a salient and critical psychological factor that is relevant for learning and operating across all contexts. As such, the evolving conditions and the existence of stress are factors that shape the needs and effectiveness of learning.

Multi-Domain Operations: Shaping Warfare Conditions and Learning Needs

As articulated in the *National Defense Strategy* (DoD, 2022), a critical security concern includes the complexity of potential threats from adversaries. For example, adversaries may operate simultaneously across domains in space, land, air, and sea, through cyber threats and unmanned vehicles, and through information disruption. In addition to the physical domains of operations, warfare has expanded across time, geography, potential actors, technology, and warfare methods, such as biological warfare, irregular warfare, and unmanned drones (*TRADOC Pamphlet 525-3-1*, U.S. Army, 2018). Thus, adversaries can operate in ways that are not only more intricate than in the past, but increasingly unpredictable and advanced, which has led the U.S. military to reorient to what is called "multi-domain operations" (*FM 3-0*, U.S. Department of the Army, 2022). Multi-domain operations refer to the coordination of military activities across all areas of threat, with the goal being to remove barriers to obtaining information and making decisions across all domains. Consequently, military learners may need competencies that will enable them to operate in environments that are characterized as increasingly volatile, uncertain, complex, and ambiguous (Baran & Woznyi, 2020; Cousins, 2018; Moore, 2014).

One consequence of this reorientation is the requirement to develop and maintain a military with the capacity to digest a broader band of information, adapt, make decisions across domains, use a broader range of physical capacities, and interact with other military elements. In other words, the competencies required to work in a multi-operational and volatile, uncertain, complex, and ambiguous environment extend beyond simply maintaining proficiency in select skillsets. Preparing to maintain competitiveness in such environments requires an expansion of competencies beyond job-specific tasks and learning a broader set of competencies than considered traditionally.

One approach to preparing military learners for complex environments is to more directly teach competencies intended to be applied across contexts, making them more inherently useful across a broad range of needs. These are often referred to as 21st century skills and include subjects such as critical thinking and interpersonal communication. As discussed in Chapter 2, these 21st century skills are encompassed within the domains of hard and soft skills, and they are the focus of many courses military learners take as they progress in their careers. A National Academies report, *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*, reviews evidence showing that 21st century skills learned prior to age 17 are important across multiple domains, such as education and work, and predict success in adulthood (National Research Council, 2012). In addition, the proliferation of technology will certainly require new competencies in the future, such as those related to human-artificial intelligence (AI) teaming, that are now being identified (see Chapter 6 for more on technology and military learning). In the military context, it may be meaningful to expand the range of competencies that are transferrable to many contexts and introduce these competencies early in the military career to enable all military learners to remain successful in a volatile, uncertain, complex, and ambiguous world.

The Observe, Orient, Decide, and Act Loop: Decision-Making Competencies and Agility Under Evolving and Stressful Conditions

Decision-making agility is an example of a 21st century skill that is increasingly relevant in the military context. Given the expansion of multi-domain operational contexts, military leaders are expected to improve their decision-making abilities to create and exploit opportunities for accomplishing larger military objectives. Much of the current thinking in this area of military doctrine was influenced by Air Force Colonel John Boyd, who formalized his views in what he called the Observe, Orient, Decide, and Act (OODA) Loop (Boyd, 1976). These basic steps are not unique in the decision-making literature, but their application in military tactics is. This doctrine emphasizes the observe and orient steps as the fundamental components for creating and exploiting opportunities, as these steps are where leaders can deconstruct the situation into individualized dimensions through observation and then reconstruct or orient their troops and equipment into an advantageous context.

According to Boyd, the value of the OODA loop lies in describing decision cycles. He believed achieving dominance on the battlefield could be reduced to creating decision-making agility, represented by increasing the frequency of decision cycles. As an analogy, he suggested considering a chess game in which one player would get two moves for every one move of the opponent (Coram, 2002). The advantage of additional adjustments in such a game would make even the worst players likely to defeat their opponents.

Educational materials for military leaders incorporate OODA concepts. For example, the Army formalizes some of these ideas in its Army Doctrine Publication (*ADP 6-0: Mission Command*, U.S. Department of the Army, 2019). Four of the seven principles of mission command are related directly to the OODA loop concept:

1. Provide a clear commander’s intent.
2. Use mission orders.
3. Exercise disciplined initiative.
4. Accept prudent risk.

These principles are designed to focus leaders on establishing clear objectives while allowing subordinates the freedom to determine their method of achieving those objectives. In addition, mission command is intended to delegate sufficient authority to subordinates to create and exploit opportunities by exercising disciplined initiative and accepting prudent risk. In military parlance, the goal is for leaders to convey the necessary information about mission goals as they pertain to the overall strategy, while subordinates are to use their knowledge, information, and opportunities to determine the tactics. The OODA loop also illustrates how the unique elements of the military context will emphasize some 21st century skills over others. Agile decision making is a competency requiring quick and accurate assessments of a situation, as well as the capacity to creatively construct possible courses of action. Doing so can be particularly difficult in a stressful context such as the military.

Despite the prevalence of the OODA loop in training and doctrine, research has not studied the OODA loop empirically as a method or measure of leadership performance. There is little clear evidence on how effective training is at improving delegation and decision making and the extent to which these ideas improve military effectiveness, especially in increasingly complex operational environments. Research is needed in developing ways to measure effective decision making and in assessing the effectiveness of training decision-making skills.

Stress and Learning[10]

Military learners need to be prepared to support their learning goals and perform under stress (Taylor, 2012). Stressors can emerge from multiple sources simultaneously. Even outside of combat, training exercises can pose substantial physical danger. Physical training may impose serious psychological and physiological stress, ranging from the so-called survival swim to the deprivations experienced during Ranger school or Navy SEAL Basic Underwater Demolition/SEAL training. Outside of these physically demanding scenarios, military learners face other persistent forms of stress associated with their roles, such as having friends and family being deployed, injured, or killed in combat, and requirements to perform morally challenging tasks, relocate, or take job assignments they do not wish to perform (National Academies, 2019; Ribeiro et al., 2023). In addition, learning in and of itself, including taking continuous courses, upholding personal expectations, and undergoing routine evaluations, can also be a source of stress (Aherne, 2001; Hughes, 2005; Vyas et al., 2017).

Foundational research has clearly demonstrated the negative effects of stress. Allostatic load, the cumulative burden of stress and life events, is a prominent theoretical construct that emphasizes the effects of stress experiences (Juster et al., 2010; Lupien et al., 2015; McEwen,

[10] This section draws directly from an expert review commissioned by the committee (Jamieson, 2024).

2003). Allostatic load models have clear implications for learning outcomes, especially in learners who might have encountered difficulties in their educational pasts.

Although stress is often perceived and experienced as negative, stress can also facilitate cognitive performance, promote growth, expand boundaries, and even serve health-protective functions (Dienstbier, 1989; Jamieson et al., 2018; Mendes et al., 2007). Thus, stress is multifaceted in that it can be both harmful and facilitatory. Without experiencing the benefits of the right kind of stress, people will underachieve, miss opportunities for growth, and even suffer from poor health. Indeed, stress facilitates learning about cues that predict positive probabilistic outcomes in adult learner populations (Lighthall et al., 2013). The notion that stress can benefit learning and performance (Crum et al., 2017) and not just harm it, is not typically represented in the way people and the media think and talk about stress (Cohen et al., 1994).

What then determines whether the stress response a person experiences is harmful or facilitatory? The biopsychosocial model of challenge and threat (Blascovich, 1999) states that stress responses are not simply the result of facing a stressful situation. Instead, individuals play an active role in constructing their own stress responses through cognitive appraisals or the ways they interpret situations. When faced with a stressor, a person cognitively appraises the demands and their potential resources, such as competencies, abilities, or social support. These interact to cause challenge- and threat-type responses in situations where people need to take on acute demands, such as learning new material (see Blascovich & Mendes, 2010; Jamieson et al., 2018; Mendes & Park, 2014 for reviews).

Individuals experience challenge when their appraisals of coping resources exceed their appraisals of what the situations demands. Conversely, threat manifests when perceptions of demands are believed to exceed resources (Jamieson et al., 2017). In other words, the type of stress experience isn’t based on the presence of a stressor; rather, it is rooted in whether a person perceives that they can (challenge) or cannot (threat) address the stressors presented to them. To illustrate this concept, imagine two military learners that are instructed to quickly learn a new technology. They face the same stressor. Learner A believes that she has the abilities and resources to successfully master this unfamiliar technology, so she interprets the situation as a challenge. On the other hand, Learner B believes that his abilities and resources are lacking, which leads him to perceive the same situation as a threat. Distinct psychological processes undergird challenge- and threat-type stress responses, and these psychological response patterns also have direct effects on biology and behavior (Brownley et al., 1999; Uphill et al., 2019).

Regarding learning engagement and outcomes, challenge-type stress states are associated with approach motivation, and threat is associated with avoidance motivation (Jamieson, Nock, & Mendes, 2013). On the other hand, challenge is generally associated with better behavioral and cognitive performance outcomes relative to someone who is relaxed or not experiencing any stress (Blascovich et al., 1999; Dienstbier, 1989; Jamieson et al., 2010). In the short-term, threat impairs decision making, and over the long term it is predictive of cognitive rigidity, accelerated brain aging, cognitive decline, and cardiovascular disease (Jefferson et al., 2010; Matthews et al., 1997). Furthermore, research has demonstrated that learners preparing to take pressurized standardized tests perform at higher levels when challenged than when threatened (Jamieson et al., 2010), and cognitive flexibility is stunted by threat-type stress responses (Mendes & Jamieson, 2012).

Many approaches to addressing the negative effects of stress have traditionally focused on removing or reducing stressors (Brooks, 2014). Recent advances in affective science suggest a new approach that optimizes stress by engaging positively with rigorous but useful social and academic stressors. This perspective seeks to maintain functional levels of sympathetic arousal, such as a racing heart or sweaty palms, while helping individuals respond with more adaptive challenge-type stress responses to stressors they normally face (Figure 5-1) (Jamieson et al., 2018).

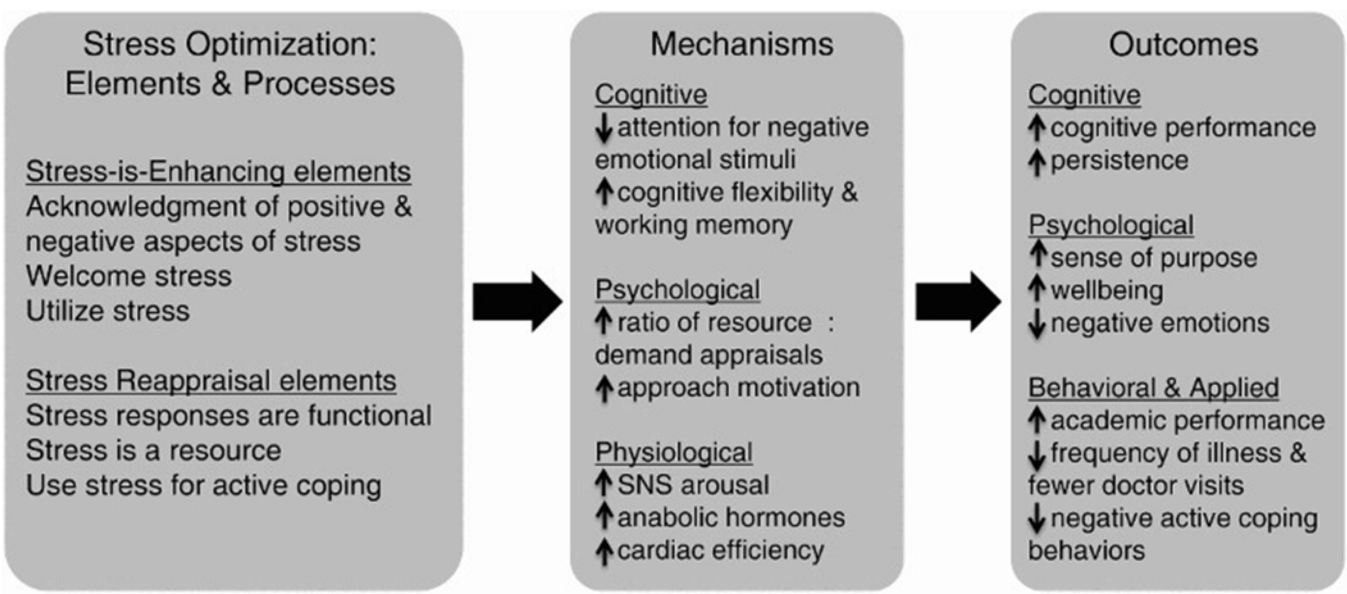

FIGURE 5-1 Stress optimization model. The first step depicts the integration of elements and processes derived from existing manipulations. These impact mechanisms then feed forward to improve outcomes.
SOURCE: Jamieson et al., 2018

For example, one of the first optimization tools developed, stress reappraisal, presents signs of sympathetic arousal experienced during stress as signs that one is engaged and ready—rather than signaling anxiety—and as resources that aid rather than hinder performance (Jamieson et al., 2010). In a double-blind field experiment, community college students—many of whom were adult learners—completed either stress reappraisal instructions that educated individuals about the adaptive benefits of stress arousal or placebo materials that instructed participants to ignore stress by trying to put it out of their minds. Reappraisal participants not only scored higher on their in-class exams, but they also reported less evaluation anxiety and higher resource appraisals, procrastinated less, and were more likely to adopt helpful performance approach goals (Jamieson et al., 2016; 2022). The emphasis on changing appraisals to improve stress responses has also been observed in other empirical contexts (Jamieson et al., 2010; 2012; Oveis et al., 2020).

An important set of limitations that moderates stress effects is heterogeneity tied to mental health processes. For instance, experiences of negative stress are frequently anxiety provoking, and chronic or repeated feelings of anxiety predict the emergence of depressive symptoms (Starr & Davila, 2012). Thus, stress can play a causal role in the development and maintenance of major mental health problems (Lewinsohn et al., 2001). While steps can be taken to interrupt the negative recursive processes through which feelings of anxiety accumulate into major depressive disorders (Yeager et al., 2016), the absence of widely deliverable preventative interventions often leads to negative stress responses spiraling into mental health problems. Having a better understanding of these and other chronic stress processes is important to supporting military learners in stressful contexts.

Relatedly, at what point exactly does stress move from being helpful to harmful? Many have written about the inverted-U theory of stress and performance, which states that low levels of stress may be unmotivating, high levels may be overwhelming, and moderate levels are optimal. There hasn't been a lot of empirical work directly testing if the relationship is U-shaped, and many have hypothesized other formations of the relationship (Corbett, 2015; Muse et al., 2003). Scholars have highlighted specific factors that may moderate the effects of stress that is perceived as outside of one's control, violates basic human needs, and induces helplessness. Researchers may explore these factors in future studies.

While many stress models are well established, notable gaps remain with direct implications for military learners. It is important that research in the stress and learning domain conducts well-powered studies with adult learners in applied settings, including studies with samples of military learners. Moving beyond formal classroom learning environments to understand stress in more naturalistic settings requires developing creative tools that build experiences to gather empirical data. For example, in a military context, the Squad Overmatch program includes a module that immerses troops in live exercises that mimic "real world" settings to help develop resilience and build skills in stressful, but controlled, situations (Ogden et al., 2015). Additionally, some research has demonstrated that individuals with military service, defined by active duty service, veteran status, or training for the Reserves or National Guard, had increased odds in the prevalence of adverse childhood experiences, compared to those without service (Bloshnich et al., 2014).

It may be important to consider how exposure to early adverse experiences may subsequently shape attitudes toward learning and the initial interpretation of situations in adulthood. For instance, researchers may consider examining if those individuals exposed to adverse experiences are more likely to interpret innocuous learning situations as stressors, and subsequently face more threat-type responses. Using research paradigms that create immersive stressful experiences as similar as possible to real-world settings is vital to applying knowledge to solve real-world problems. However, it is difficult to study stress if the individual is not actively experiencing stress. Moreover, learning under stressful conditions may make it more likely that any newly acquired competencies can more easily translate to future stressful situations, because the learning environment is matched in terms of stress to the application environment. Applying intervention tools in more lifelike settings may help to bolster the success of military learners.

Finally, the range of emotions experienced by individuals in working and educational contexts—such as joy, boredom, and shame—is closely related to stress (Pekrun et al., 2002). There is a burgeoning body of research demonstrating that emotions may have critical implications for learners and their academic success (Camacho-Morles et al., 2021; Jorgesen et al., 2021). Additional research is needed to fully explore the impact of emotions on learning outcomes in the military context.

MILITARY CULTURE AND MILITARY LEARNING

The following section discusses how military culture affects learning, starting with equity issues and then highlighting three prominent characteristics of military learning environments in the context of military culture: hierarchy, collectivism, and respect. The discussion will delve into how these characteristics set strong expectations about how learners can behave and consequently how military learners can navigate the learning pathways.

Equity Factors and Implications for Military Learners

As military learners complete training and education opportunities and aim to learn on the job, they may encounter situational factors associated with diversity and equity that can have meaningful effects on learning and subsequent performance. This is particularly true for those who have been historically minoritized[11] in the military and those who currently remain a numeric minority. As described below, within the hierarchy of the military, the enlisted corps is racially and ethnically diverse, while the officer corps is much less diverse.[12] Across the enlisted corps and officer corps, and among DoD civilians, women are substantially underrepresented relative to the civilian sector.

Demographic Representation of the Military

The U.S. military was originally founded as a predominately White and male organization. Individuals who did not meet those demographic characteristics faced systematic disadvantages, either by being excluded from participation or by encountering significant barriers. Women were not eligible until 1948, when President Harry S. Truman signed the Women's Armed Service Integration Act (Lopez, 2023), and in that same year President Truman signed an executive order that mandated the racial desegregation of the military (Executive

[11] Terminology and definitions pertaining to demographic characteristics and categories, including gender, sex, race, and ethnicity, are complex and continuously shifting. This chapter includes the terms that were used in the referenced literature.

[12] Interested readers are referred to Harrison & Klein (2007) for a discussion of approaches for measuring diversity.

Order 9981, 1948). Within recent history, the policy “Don’t Ask, Don’t Tell,” which had permitted the military to discharge service members for being openly gay or lesbian, was overturned in 2010, (National Archives Foundation, n.d.). While numeric representation in the military has improved over time, minoritized individuals, in particular women and racial/ethnic minorities, still face significant barriers and remain numerically underrepresented in some sectors of the military today (Fleming et al., 2023; Laurence, 2017).

The committee reviewed published data from the DoD 2022 demographics report to understand the current numeric representation of individuals in the military by race/ethnic and gender identities (*2022 Demographics: Profile of the Military Community,* U.S. DoD, 2022). To better contextualize these data, it is crucial to first consider the demographic composition of the United States. Data from the U.S. Census indicate that females represent approximately 50.9 percent of the population (U.S. Census Bureau, 2023). Regarding race and ethnicity, Non-Hispanic White individuals represent the majority of the population (57.8%), followed by Hispanic or Latino (of any race) individuals (18.7%), and then Black or African American individuals (12.1%). Non-Hispanic individuals of the following racial groups, American Indian and Alaskan Native, Asian, Native Hawaiian and Other Pacific Islander, Some Other Race, and Multiracial together represent 11.4 percent of the population (Jensen et al., 2021).

Across the total military force, which includes all active-duty personnel, DoD civilians, and reserve and Guard forces, men represent the majority of the military population at approximately 81 percent. More than 70 percent of the total force identified as White, while 17.0 percent identified as Black or African American, 5.1 percent as Asian, 1.1 percent as Native Hawaiian or Other Pacific Islander, and 1.0 percent as American Indian or Alaska Native. Regarding ethnicity, individuals who identify as either Hispanic or Latino represent 17.3 percent of the total military force, while the remaining 82.7 percent do not identify as either Hispanic or Latino (*2022 Demographics: Profile of the Military Community,* U.S. DoD, 2022). Similar patterns of gender and race representation are observed when just looking at data for active-duty members, a subset of the total military force. Specifically, men represent 82.5 percent of active-duty members, and 68.8 percent identify as White.

When considering the hierarchy of the military, the enlisted corps is racially and ethnically diverse, while the officer corps is much less diverse (Table 5-1). DoD found that among active-duty members, the largest percent of racially minoritized individuals (35.3%) are in pay grades E7 to E9, while only 12.7 percent are in pay grades O7 to O10 (*2022 Demographics: Profile of the Military Community*, U.S. DoD, 2022). Furthermore, among active-duty members in higher-ranking O7 to O10 pay grades, Black or African American individuals represent approximately 7.7 percent of the total, whereas White individuals represent 87.9 percent of this grade (Table 5-1).

TABLE 5-1 Number and Percentage of Active-Duty Members by Race and Pay Grade

Pay Grade	American Indian or Alaska Native		Asian		Black or African American		Native Hawaiian or Other Pacific Islander		Multi-racial	
	N	%	N	%	N	%	N	%	N	%
E1–E4	5,291	1.0	27,926	5.1	106,577	19.5	6,522	1.2	14,243	2.6
E5–E6	4,959	1.3	19,683	5.0	74,536	19.1	5,711	1.5	17,045	4.4
E7–E9	2,133	1.6	5,510	4.2	23,657	18.0	2,074	1.6	3,671	2.8
W1–W5	161	0.8	752	3.9	3,154	16.4	164	0.9	132	0.7
O1–O3	1,007	0.8	9,168	6.9	11,580	8.8	825	0.6	4,345	3.3
O4–O6	504	0.6	4,402	5.2	6,722	8.0	440	0.5	1,519	1.8
O7–O10	4	0.5	13	1.5	67	7.7	1	0.1	6	0.7
Total	14,059	1.1	67,454	5.2	226,293	17.3	15,737	1.2	40,961	3.1

Pay Grade	Unknown		Racial Minority Group Total		White		Total DoD	
	N	%	N	%	N	%	N	%
E1–E4	6,095	1.1	166,654	30.5	379,821	69.5	546,475	100.0
E5–E6	13,427	3.4	135,361	34.7	254,829	65.3	390,190	100.0
E7–E9	9,276	7.1	46,321	35.3	84,770	64.7	131,091	100.0
W1–W5	1,756	9.1	6,119	31.7	13,163	68.3	19,282	100.0
O1–O3	7,399	5.6	34,324	25.9	97,996	74.1	132,320	100.0
O4–O6	4,909	5.8	18,496	21.9	66,000	78.1	84,496	100.0
O7–O10	14	1.6	105	12.1	761	87.9	866	100.0
Total	42,876	3.3	407,380	31.2	897,340	68.8	1,304,720	100.0

SOURCE: *2022 Demographics: Profile of the Military Community*, U.S. DoD (2022).
NOTE: Racial minority groups include American Indian or Alaska Native, Asian, Black or African American, Native Hawaiian or Other Pacific Islander, Multi-racial, and Unknown. Displayed percentages may not total 100% due to rounding.

The 2022 DoD report included demographic data of the reserve components, which included the following: DoD's Army National Guard, Army Reserve, Navy Reserve, Marine

Corps Reserve, Air National Guard, Air Force Reserve, and the Department of Homeland Security's Coast Guard Reserve (*2022 Demographics: Profile of the Military Community,* U.S. DoD, 2022). The report found that the largest percentage of women were represented in the Air Force Reserve at 28 percent, while the smallest percent of women were in the Marine Corps Reserve at only 4.4 percent (see Table 5-2). When looking at the racial representation within these reserve components, the Navy Reserve had the largest percentage of enlisted individuals who identified as a racial minority (42.7%).

Although women are more represented within the DoD civilian workforce than they are among active duty military, women are still substantially underrepresented. Specifically, women comprise 31.7 percent of the DoD civilian workforce; by comparison, women comprise 43.4 percent of the total federal employee workforce across all agencies (*GAO-23-105284*, U.S. GAO, 2023). The racial and ethnic demographics of the DoD civilian workforce more closely parallel the enlisted corps than the military officer corps: among DoD civilians who provided demographic responses, 66.79 percent identify as White (*GAO-23-105284*, U.S. GAO, 2023). Notably, women and racial and ethnic minorities are far more underrepresented in higher-paying DoD civilian positions than they are in lower-paying DoD civilian positions. For example, women comprise 73.87 percent of the DoD civilian workforce serving in the five lowest GS paygrades (GS-1 through GS-5), but only comprise 22.17 percent of the workforce at the highest GS pay grade (GS-15) (*GAO-22-105130*, U.S. GAO, 2022). Likewise non-White employees comprise 45.93 percent of the DoD civilian workforce in the five lowest GS paygrades, but only comprise 19.35 percent of those in the highest GS pay grade (GS-15) (*GAO-22-105130*, U.S. GAO, 2022). Further GAO analysis showed that—when controlling for factors such as occupation, education level, and veteran status—non-White DoD civilians are significantly less likely to be promoted than their White counterparts (*GAO-22-105130*, U.S. GAO, 2022).

TABLE 5-2 Percentage of Enlisted Members and Officers in the Selected Reserve by Gender and Reserve Component

Reserve Component	Enlisted (%)		Officers (%)		Total (%)	
	Male	Female	Male	Female	Male	Female
Army National Guard	80.1	19.90	84.0	16.0	80.7	19.3
Army Reserve	74.6	25.4	74.6	25.4	74.6	25.4
Navy Reserve	73.0	27.0	79.7	20.3	74.7	25.3
Marine Corps Reserve	96.2	3.8	91.4	8.6	95.6	4.4

Air National Guard	77.9	22.1	79.6	20.4	78.2	21.8
Air Force Reserve	71.8	28.2	72.7	27.3	72.0	28.0
Total DoD	**78.2**	**21.8**	**79.3**	**20.7**	**78.4**	**21.6**
Coast Guard Reserve	84.2	15.7	73.2	26.8	82.4	17.6
Total Selected Reserves	**78.2**	**21.8**	**79.3**	**20.7**	**78.4**	**21.6**

SOURCE: *2022 Demographics: Profile of the Military Community*, DoD (2022).
NOTE: Displayed percentages may not total 100% due to rounding.

Inclusion and Learning

In addition to numeric representation, issues associated with inclusion are also critical for military members (Erwin et al., 2024). For example, a recent landmark report of the Fort Hood Independent Review Committee found that the command climate at Fort Hood was permissive of sexual harassment and sexual assault, putting women in particular at risk for harm (Fort Hood Independent Review Committee, 2020). Therefore, the committee looked beyond numeric representation and examined factors related to inclusion—specifically stereotyping, interpersonal mistreatment, and instructor-learner similarities. The following section also discusses the ways in which these equity factors shape learning for military learner.

Stereotypes: Attitudes, Perceptions, and Threats[13]

Everyone holds certain stereotypes, sets of generalized beliefs regarding the characteristics of groups of people (National Academies, 2023). Stereotyping as it pertains to social identity groups—such as race, ethnicity, or gender—can be particularly harmful within the context of training and education for a number of reasons (Steele, 1997). For example, military contexts place a cultural emphasis on stereotypical masculine traits such as assertiveness, intelligence, competitiveness, agency, self-confidence, and aggressiveness (Reis & Menezes, 2020; Richard & Molloy, 2020; Spector-Mersel & Gilbar, 2021). These traits have been perceived as not only stereotypical to being a man (Eagly & Karau, 2002), but also believed to be essential characteristics of many military occupations (Do & Samuels, 2021; Pendlebury, 2020). On the other hand, women are often stereotyped as being passive, communal, and nurturing, facilitating the perception that women are incompatible with the military and many

[13] This section on stereotype threat draws partially on an expert review commissioned by the committee (Jamieson, 2024).

military occupations (Laurence et al., 2016). These perceptions of compatibility can inform the specific training and education pathways individuals initially pursue and on which they are willing to persist (Phillips, 2024; National Academies, 2020; Schuster & Martiny, 2017).

To illustrate, scholars have noted that gender stereotypes have informed perceptions and acceptance of women occupying combat roles. In 2013, the DoD removed the policy that restricted women from serving in combat (Vergun, 2013). Although women are now permitted, studies have demonstrated that some individuals adhere to stereotypic beliefs: that women are inferior in such roles and that their integration into combat roles may result in national security concerns (Collins-Dogrul et al., 2017; Doan & Portillo, 2019). These stereotyped beliefs may result in unequal support of women pursuing specific occupations or roles that are combat-based, may inform expectations about women's military roles (Matthews et al., 2009), and may ultimately shape individuals' training and educational trajectories. Stereotyped assumptions about gender, roles, and placement in the military have been seen as early as the recruitment phase (Yeung et al., 2017) and may determine who enters the military. The importance of challenging stereotypes of women in other male-dominated fields, such as science, technology, engineering, and mathematics (STEM), has been discussed as a way to increase women's interest in those fields and boost a sense of belonging (National Academies, 2020)

Related to stereotyping is the concept of stereotype threat. Stereotype threat emphasizes that when evaluating demonstrations of learning competency in light of a negative stereotype about a demographic group a learner belongs to—e.g., negative stereotypes about African Americans' intellectual capabilities or negative stereotypes about women in STEM—anxieties about performance in stereotyped domains can negatively affect members of these minoritized groups (Steele & Aaronson, 1995). Some research has demonstrated that stereotype threat is associated with underperformance on tests, including physical and subject-specific tests, and reduces motivation to learn (Walton et al., 2015). Studies have shown that increases in anxiety-centric affective responses exert a negative effect on learning and achievement outcomes, especially in uncertain stressful situations. For example, higher levels of learning and evaluation anxiety are associated with negative, threat-type stress responses and subsequent poor achievement outcomes (e.g., Mattarella-Micke et al., 2011).

There are some important limitations and caveats to the findings on stereotype threat, however. First, although researchers have typically found an effect for stereotype threat, effect sizes tend to range from negligible to small, particularly in field settings (Cullen et al., 2004). Moreover, some have noted the presence of publication bias in the literature (Priest et al., 2024; Shewach et al., 2019; Warne, 2022), which serves to suppress publication of null effects and may lead to the impression that the research results are more consistent than they actually are. Importantly, scholars have found that removing stereotype threat does not eliminate group differences on performance outcomes; differences that may be due to larger structural inequities, such as uneven educational opportunities (Sackett et al., 2004).

Interpersonal Mistreatment

As the military continues to diversify, feelings of belonging are more relevant than ever for maximizing learning outcomes. Feeling a sense of belonging frequently guides how much members of minoritized groups achieve and sustain in learning environments (Bodamer, 2020). Interpersonal mistreatment, including sexual harassment or sexual assault, can potentially undermine feelings of belonging (Hershcovis et al., 2017) and yield downstream consequences that may further undermine learning (Fort Hood Independent Review Committee, 2020). Increasing evidence from the military and comparable educational contexts has demonstrated that individuals who have been minoritized, including women, racial and ethnic minorities, and individuals with LGBTQ+ identities, may be disproportionately affected by these forms of interpersonal mistreatment (Acosta et al.,2021; Jagsi et al., 2023; National Academies, 2018b; Vargas, et al., 2021).

For example, experiences of harassment are associated with adverse psychological health outcomes and well-being, such as increased depressive symptoms, anxiety, and distress (Bondestam & Lundqvist, 2020; Chan et al., 2008; Klein & Martin, 2021); reduced feelings of trust in the military system (Rabelo et al., 2019); decreased psychological safety; and reduced feelings of belonging (Aycock et al., 2019; Siad & Rabi, 2021). Experiences of harassment are associated with a range of negative outcomes, including increased absences, reduced motivation, decreased engagement, and dropping classes or school altogether (Bondestam & Lundqvist, 2020). Although most of this research has been conducted outside of the military context, these patterns of findings have been observed in multiple contexts (Bondestam & Lundqvist, 2020; National Academies, 2018b).

Perceived Unequal Opportunities for Informal Learning Through Mentorship and Feedback

The Department of the Air Force[14] conducted disparity reviews in 2020 and 2021, and although the reviews revealed widespread perceptions of racial, ethnic, and gender discrimination within the operational Air Force, equity concerns related to formal military training and education were uncommon. Rather, the results from focus groups suggested that equity issues may primarily influence informal rather than formal learning contexts in the military (*S8918P*, The Inspector General of the U.S. Department of the Air Force, 2021). While we can only speculate as to the reasons why discrimination may be more likely to occur in on-the-job training than in formal military training and education environments, we note that in other contexts, greater structure and formal standardization often mitigate bias (see, for example, Baltes et al., 2007; and Levashina et al., 2014).

The disparity reviews found widespread perceptions of bias toward Department of the Air Force military members and DoD civilians who are racial minorities or female. For example, 41 percent of racial and ethnic minority respondents and 45 percent of female respondents said they had to "work harder than" their White and male peers "to prove they were competent at their job" (The Inspector General of the U.S. Department of the Air Force, 2020, p. 7). The focus groups identified both formal enlisted basic military training and technical training as areas in which racial and ethnic minoritized individuals were generally treated equally (*S8918P*, The Inspector General of the U.S. Department of the Air Force, 2021, p. 193). However, focus groups reported substantial disparities in interpersonal treatment after formal training by on-the-job supervisors, who are responsible for both formal and informal on-the-job training (*S8918P*, The Inspector General of the U.S. Department of the Air Force, 2021, p. 193). Over 40 percent of Black Department of the Air Force survey respondents—39 percent of enlisted personnel, 54 percent of officers, and 41 percent of DoD civilians—indicated they do not believe Black members "have the same opportunities for mentorship, feedback, and role models as others in [their] organization," and approximately half of Black Department of the Air Force members indicated they believe "racial bias exists in the way [their] leadership provides informal feedback, mentoring, and formal verbal counseling" (*S8918P*, The Inspector General of the U.S. Department of the Air Force, 2020, p. 92-93).

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[14] As a Department of the Air Force study, both Space Force and Air Force members were surveyed.

Instructor Demographic Factors and Equity Effects

In recent years, some senior military leaders have emphasized the importance of having an instructor corps that is as demographically diverse regarding gender and race/ethnicity as the population it serves and have undertaken targeted recruiting efforts with the goal of increasing instructor diversity (e.g., Currier, 2003; Hadley, 2022; *GAO-22-105130*, U.S. GAO, 2022). Although such efforts may have many benefits, one potential effect of increasing instructor diversity is an increased likelihood that underrepresented groups within the military (e.g., females and racial/ethnic minorities) would be more likely to be exposed to instructors that share their same demographic characteristics. Generally, the body of research in this area demonstrates that instructor and learner perceptions may shape important learning outcomes (Blake-Beard et al., 2011; Dennesen et al., 2022; Wang et al. 2018). However, the committee is not aware of research that has isolated the mechanisms contributing to demographic similarity effects in the military context. As such, this section reviews research on the role of instructor/learner similarity on achievement and career persistence, drawing from research conducted in K–12 and civilian university settings.

Black or African American learners at the military Service academies have historically had substantially higher attrition rates than other learners. For example, from 2016 to 2021, 61 to 86 percent of Black and African American learners graduated from the U.S. Air Force Academy within four years, compared to 80 to 91 percent of White, Asian, Hispanic or Latino learners and learners of two or more races. During the same time period, the graduation rate for Black and African American learners graduating from the U.S. Naval Academy ranged from 72 to 86 percent, compared to 83 to 95 percent of White, Asian, Hispanic or Latino learners and learners of two or more races (*GAO-22-105130*, U.S. GAO, 2022). Although there are likely many contributing causes, including inequities in academic preparation before entering the Service academies, perceptions among Black and African American learners suggest that differences in instructor behaviors towards Black and African American learners may contribute to the gap in retention.

In focus groups conducted by the U.S. GAO (*GAO-22-105130*, 2022), many Black and African American learners at the military Service academies indicated a perception that their military instructors are racially biased.[15] Although female and LGBTQ+ learners at military Service academies generally did not perceive their instructors as biased or discriminatory, Black and African American learners in many cases reported differential treatment from military faculty. A prominent theme was the perception of a culture in which faculty often presume, incorrectly, that Black and African American learners were recruited primarily as athletes and doubt their academic abilities. Such differential treatment included being singled out or facing additional scrutiny. Learners expressed the perception that Black and African American learners are punished more harshly than other learners for similar offenses,[16] citing examples ranging from minor infractions to offenses resulting in separation from the academy. Although Black and African American learners generally viewed their civilian instructors as working well with learners from diverse backgrounds, they expressed more concerns about military faculty (*GAO-22-105130*, U.S. GAO, 2022).

Instructor-Student Similarity: Gender

Gender differences in military training completion and training grades, where present, can sometimes be explained fully by differences in prior experience, aptitude, knowledge, and test scores at entry (Schulker et al., 2018, p. 48-52). In some military contexts, research has shown that female cadets perform worse than their male counterparts in required math coursework than would be predicted based on their aptitude test scores at entry, but there is some evidence that having a female instructor may help eliminate this gap (Carrell et al., 2009). One large-scale study found that when high-ability female cadets had a female instructor for their introductory STEM course at the U.S. Air Force Academy, they achieved higher grades in both the introductory and subsequent STEM courses taught by other instructors and were more likely

[15] The 2022 GAO report notes that the Office of People Analysis (OPA) was in the process of revising the Defense Equal Opportunity Climate Survey (DEOCS) to more systematically capture the prevalence of perceived discrimination at the military Service academies. However, we could locate no publicly available reports detailing subsequent DEOCS results for the Service academies.

[16] Perceptions of discrimination may not always be substantiated. However, the 2022 GAO report recognizes that discrimination and harassment are often not formally reported or adjudicated. For example, the GAO report notes that, "DOD-level guidance indicates that the chain of command is the primary and preferred channel for identifying and correcting unlawful discriminatory practices and resolving complaints of harassment," rather than the formal complaint processing system, and Service-specific guidance encourages resolving complaints at the lowest possible level (p. 14). Additionally, many organizational studies outside of the military demonstrate high prevalences of discrimination and harassment that are often never formally reported to authorities, often because those subjected to discrimination or harassment fear reprisal (Feldblum & Lipnic, 2016).

to graduate with a STEM major (Carrell et al., 2009). However, among lower-ability cadets, only the grades in the introductory courses benefitted. Although some similar studies in civilian universities have reached different conclusions, these civilian studies do not translate fully to the military because of differences in potential self-selection biases. Learners in civilian universities are free to choose their own schools, courses, and professors, whereas the military academies assign learners randomly to core introductory classes, so the learners do not have the opportunity to select their instructor or initial classes (Carrell et al., 2009). Additional research across a range of military training contexts is needed to fully explore the potential impacts of gender similarities.

Instructor-Student Similarity: Race and Ethnicity

Outside the military, racially minoritized individuals often have less successful training outcomes than predicted based on their initial aptitude and knowledge test scores at entry (Maxwell & Arvey, 1993; Schmidt, 1988). Research has found a similar pattern in some military training contexts, although this difference is not always found for all racially minoritized groups (Carretta, 1997; Roberts & Skinner, 1996; Schulker et al., 2018, p. 48-52). Although the committee is not aware of any studies in the military context that have examined the effect of same-race instructors on training outcomes, findings from the U.S. Military Academy do show that randomly assigned formal mentors have a greater effect on cadets' occupational choices when they share the same race or gender (Kofoed & McGovney, 2019).

In elementary education, there is some evidence that learners assigned to teachers of the same race have greater academic achievement than those taught by instructors of a different race. In what is perhaps the most methodologically rigorous evidence for the benefit of same-race teachers, one group found that random assignment to a same-race teacher increased math and reading achievement scores of both Black and White learners (Dee, 2004, 2005). Although some methodologically rigorous studies have subsequently affirmed the findings in later grades (Clotfelter et al., 2007; Egalite et al., 2014), findings regarding the effect of same-race teachers on academic achievement have been mixed, with some studies finding a same-race teacher benefit only for minoritized individuals (Ehrenberg & Brewer, 1995) and others failing to replicate effects when including additional control variables such as prior aptitude scores (Howsen & Trawick, 2007). A study in the university context found that minoritized college learners are more likely to persist in a STEM major when they enroll in classes taught by minoritized, as compared to White, faculty members (Price, 2010). Such findings, if found in military training contexts, may support efforts to actively recruit minoritized individuals as instructors.

Mentor-Mentee Similarity and the Potential Role of Instructors as Mentors

As described, the findings of the 2020 and 2021 Department of the Air Force disparity reviews highlighted the perception that female and racial minority members do not experience the same opportunities for informal learning through mentorship and feedback as their White male counterparts. To the extent that females and racial minorities may not experience the same level of mentorship and feedback as other military members on the job, the potential role of instructors as informal mentors may take on particular importance.

Outside the military, research shows that mentor-mentee similarity can have large effects on perceived instrumental support, psychosocial support, and relationship quality in both workplace and academic settings (Dickson et al., 2014; Eby et al., 2013). Some have theorized that similar backgrounds can facilitate mutual understanding and mentoring behaviors that are more consistent with the mentee's own identity and expectations (O'Brien et al., 2010). Perceptions of mentor support and relationship quality, in turn, can have substantial effects on mentee outcomes such as learning, turnover intent, and perceived career success (Dickson et al., 2014; Eby et al., 2013). Studies have operationalized "similarity" in a number of ways, with one group of investigators (Eby et al., 2013) distinguishing three types:

- "Deep-level similarity, or overall ratings of similarity, or similarity in attitudes, values, beliefs, or personality,"
- "Experiential similarity in education and work background," and
- "Surface-level similarity, such as similarity in demographics such as race and gender."

Overall, research shows deep-level similarity, and, to a lesser extent, experiential similarity are more strongly related to mentoring relationship quality and instrumental support than surface-level similarity (Eby et al., 2013). For example, as Chapter 3 noted, military instructors may be better suited than civilian instructors to serve as mentors to their learners because they are able to draw on shared military values and shared military experience when providing advice. Consistent with this, quantitative results show that the military Service academy cadets rate active-duty military faculty as having a significantly greater influence than civilian faculty on learning military core values, interpersonal leadership development, and the ability to connect classroom content to the military (Keller et al., 2013).

Although perceptions of demographic similarity are, in most cases, not amenable to change, perceptions of deep-level similarity and, to a lesser extent, experiential similarity are subject to change as people interact and learn more about others. Promising research suggests that even brief interventions to highlight deep-level and experiential similarities between teachers and learners can improve teacher-student relationships and subsequent student achievement. One investigator, summarizing a large body of social psychological research, showed that perceived similarity has a powerful effect on who will develop positive relationships across a variety of contexts (Cialdini, 2009).

In the educational context, another group demonstrated a simple intervention in which high school teachers and learners responded to a short questionnaire regarding their interests and preferences. Those assigned to the experimental condition received feedback on five of the similarities they shared (Gehlbach et al., 2016). Results showed sustained increases in perceived similarity, improved teacher-student relationships, and higher course grades for learners in the experimental condition. In a context in which 80 percent of the instructors were White, the intervention to highlight teacher-student similarity had little to no effect on White learners' grades or relationships with their teachers, but significantly improved grades and teacher-learner relationships for Black and Hispanic individuals (Gehlbach et al., 2016).

Military Characteristics: Hierarchy, Respect, Collectivism

The following section reviews prominent cultural characteristics of the military and describes the implications for individual military learners.

Hierarchy

As an organization, the military maintains a rigid hierarchical structure in which power and status are correlated (Fiske et al., 2016; Hofstede, 1980; National Research Council 2014). For instance, military members who are at the beginning stages of their careers at the E1 level do not experience some of the same privileges afforded to senior enlisted members who are at the E-7 to E-9 levels (*U.S. Military Rank Insignia*, U.S. DoD, n.d.). Hierarchy is communicated in multiple ways, such as the insignia on military uniforms. The hierarchical structure can directly shape behaviors of an individual learner by setting rules around behaviors. According to the Uniform Code of Military Justice, leaders have the authority over their subordinates in the chain of command to maintain good order and discipline (Redmond et al., 2015). Within these chains of command, military learners need to be cognizant of who their superior is and who is their subordinate. These chains define individuals' roles, specific job responsibilities, appropriate lines of communication, and the amount of power and autonomy one has over decision making within a given context (Atuel & Castro, 2018). Recent evidence demonstrates that rank hierarchies affect how military members interact with one another and that power differentials can bias decisions, even those of military physicians (Schwab & Singh, 2024).

Respect

Related to hierarchy, respect is an integral part of the military culture. Military members are expected to demonstrate signs of respect through customs and courtesies across military learning environments, such as saluting a higher-ranking officer. These behaviors reaffirm the hierarchical chain of command (Golubiewski, 2009; Military OneSource, 2024; Redmond, 2015). Some military members show respect for their superiors by using formal titles or saying "yes ma'am" or "yes sir" when communicating with senior military members. An example of a courtesy is standing at attention until the officer or senior leader in charge advises the junior member to be at rest, to enter the room, or to sit. Other examples include following expectations of when and how to wear a uniform, being on time, and understanding how to behave at specific events (Military OneSource, 2024). In the classroom, signs of respect for the instructor can reinforce the norm of respect in military classrooms and can potentially support learning by preserving an orderly classroom. However, it may make some learners reluctant to voice appropriate questions or disagreements or create distance between the learner and the instructor.

Collectivism

Military service emphasizes and enforces collectivism—the extent to which people work together to achieve a common goal (Hofstede, 1980; Lee, Park & Koo, 2015). As discussed in Chapter 4, collectivism is a value that varies at the individual level due to a number of factors and has important implications for goal selection and persistence for learning. Regardless of one's personally held values, however, it is an expectation that individuals in the military will adhere to the prominent collectivist culture. For instance, at the micro level it is expected that individuals will train and work together in small units or teams in the military (see Chapter 3 for more on teams) (McCaslin et al., 2021). In fact, the 2014 National Research Council report on military environments concluded that teams and multisystem teams constitute an important source of context for the behavior of individuals and small units in military environments (National Research Council, 2014). At a macro level, military members have uniquely volunteered to serve a greater good and uphold freedom in the United States. Therefore, in addition to having a focus on oneself, military learners also need to navigate the learning pathways in ways that prioritize interdependence, group goals, cooperation, and other collective efforts (Marcus & Le, 2013).

Autonomy Implications for Military Learners

Even though all learners have an innate need to maintain personal autonomy (Chapter 4), the military's cultural characteristics create power distances and set caps on how much individual autonomy one can realistically acquire. Junior military learners often lack power compared to senior military learners. In addition to age, there remains a historical legacy of power distance between officers and enlisted personnel. Traditionally, members of the officer corps were perceived as having greater competencies, responsibilities, and power over enlisted personnel. This perception created a dichotomy of power of officers over enlisted individuals (Fust & Howard, 2021). While there has been a shift away from this sentiment and a shift from a strong power divide in recent times (Fust & Howard, 2021), these two categories of service members often enter into the military with different levels of education and may follow different professional trajectories that can vary by power (see Chapter 2 for a complete discussion on the formal learning pathways).

Power distance between individuals is present in many relationships, and it affects processes and outcomes across organizations (Daniels et al., 2014). Although the committee was unable to find research focused on the effect of power distance on military learning specifically, there is evidence that power distance can affect an array of important outcomes associated with learning. For example, a meta-analysis found increases in power distance were associated with decreased likelihood of seeking feedback, team commitment, and preference for teamwork (Taras et al., 2010). Moreover, motivation for training and development activities tends to be higher when people have the autonomy to choose the development activities in which they engage (Baldwin et al., 1991), which may be less likely in high power-distance relationships.

According to self-determination theory, the need for autonomy will also affect an individual's motivation for an activity because it is inherently interesting or enjoyable (Deci & Ryan, 1991), and motivation will be reduced in the absence of autonomy. Additional research is needed to examine how these structures may affect the perceived values of learning opportunities.

CONSIDERATIONS FOR MILITARY RECRUITMENT, RETENTION, AND LIFE AFTER THE MILITARY

The following section articulates how certain motivations of military members affecting learning may be particularly salient at specific time points in the military career. That is, military members do not learn in a vacuum. The military context (as described in Chapter 2) determines the types of knowledge and skills that a given military member will be expected to learn, and how and when they will be expected to learn them. As described in this present section, military recruitment, promotion, and retention processes can also influence members' motivations to learn. We discuss here some of the considerations that may influence motivation to learn, including intrinsic and extrinsic motivations to learn what is required to continue serving in the military, learn what is required to compete successfully for military promotion, and, particularly for those who are not interested in a long-term military career, learn what may prepare them for future civilian employment.

Recruitment

At the initial point of entry when recruits are around 18 years old, many may be motivated to join the military because of the immediate tangible benefits, such as gaining occupational or educational experience. In fact, recent data from the DoD's Joint Advertising Market Research and Studies survey, as well as the motivational literature discussed in Chapter 4, support these goal-oriented motivations (*24-P-0250*, U.S. DoD, 2023). This survey found that among a sample of almost 5,000 youths ages 16 to 24 years, the top five reasons corresponded to tangible benefits, including pay/money, the ability to pay for future education, travel, health, and medical benefits, and to gain experience and work skills.

Historically, enlisted military service provided a pathway to obtain a college education through its generous benefits for college funding post-military service. However, as free community college has become available across the country, the military has experienced substantial drops in recruitment (Brown et al., 2023). In light of this change, much of the financial value of military service has shifted to depend heavily on the competencies developed while in the military. The long-term value of the competencies acquired and the extent to which they reflect the larger labor market trends may affect intrinsic motivation for enlisting and learning in the military.

Assessing whether military service provides additional *marketable* competencies enables one to determine the extent to which military training is effective at teaching *enduring* competencies. However, the lifelong effects of military service are difficult to assess, given the substantial self-selection into military service. One group of investigators did show that enlisting in the Army improves earnings and education, particularly for minority enlistees (Greenberg et al., 2022). They compared lifelong outcomes of those who just barely qualified to enlist to those who were just below the Armed Services Vocational Aptitude Battery (ASVAB) cutoff, thereby creating a comparable group of individuals who had already self-selected into military service. Their findings suggest military service may provide valuable human capital development.

At the same time, there is also the concern that military service may have lifelong detrimental effects as a result of deployment and combat. Somewhat surprisingly, though, one study found that deployment to combat has no meaningful impact on lifelong earnings, employment, or disability when compared with other military veterans who were not deployed (Bruhn et al., 2024).

Other attempts to identify the extent to which learned competencies in the military may affect future earnings and life outcomes include one study that found no evidence that military service increases a veteran’s propensity to be an entrepreneur (Phipps & Skimmyhorn, working paper). However, another study found that a recruit’s initial job within the Army meaningfully changes their long-run career choices (Bruhn et al., forthcoming). For example, new recruits randomly moved into mechanical maintenance are more likely to pursue a career as mechanics after they leave the Army. The findings indicate that veterans who apply skills gained from their military roles to related civilian careers tend to outperform other veterans in similar jobs who may not have directly relevant military experience. Taken as a whole, while the military provides important learning opportunities, the connections between military and civilian sectors in terms of skillsets, positions, and lifelong effects on retired military learners may need to be explored further.

Leveraging Learning Before Enlisting to Meet Military Entry Standards

To join the military, potential recruits have to successfully overcome barriers for entry. When considering joining the military, there are strong incentives for potential recruits to engage in learning opportunities that will help improve their performance on entry tests to qualify for enlistment and for specific desired military occupations or to obtain a college degree to qualify for commissioning and specific desired officer occupation. Improved test performance or attainment of degrees in specific fields can broaden the range of military jobs a potential recruit qualifies for and can help maximize personal autonomy and alignment with career trajectories that are personally fulfilling. Thus, this initial recruitment period can have a substantial impact on what an individual will be doing within the military and how their career may advance in the future.

For enlisted personnel, fluid and crystallized abilities are initially measured with the ASVAB (see Chapter 2 for their pathway). Math and verbal scores determine eligibility to join the military, and when combined with specific subtests these scores determine eligibility for specific occupations (*23-S-0439*, DoD, 2022). Higher scores allow enlisted recruits to qualify for more occupations, increasing the likelihood that they will be able to pursue an occupation that is aligned with their personal interests. For example, the Cyber Operations career field requires higher math and verbal ability scores than Human Resources or Nursing. To qualify to enter training to become an aircraft mechanic, Air Force recruits, for example, need to obtain a minimum score on the ASVAB mechanical aptitude composite, which combines scores on verbal, math, auto shop, and mechanical comprehension subtests.

Potential officers, on the other hand, are required to obtain an undergraduate degree before joining the military (see Chapter 2 for their pathway). Pursuing higher education and performing well in college in specific majors can affect a prospective officer's opportunity for selecting their job within the military. For example, to enter the military in an engineering or science career field, officers need a related degree. As young adult military members navigate some of the earliest learning opportunities at this entry point, they benefit from strong psychological flexibility and high levels of cognitive fluid abilities. It is during this period that they are establishing a career trajectory and their sense of purpose (Chapter 4).

Promotion and Retention

First-term military members commit two to six years of active duty service. As of 2020, the average number of years in service among enlisted personnel is just over six years (*U.S. Armed Forces at Home and Abroad*, U.S. Census Bureau, 2020), meaning the vast majority of members leave the military to start a second career. Even for those who plan to separate shortly after their initial service commitment, learning while in service may be largely motivated by a desire to bolster their options for a post-military career. Regardless of whether military members plan to stay or go, they are interested in learning and development. For example, although the "Opportunity to Serve My Country" was the most common reason uniformed Army members cited for wanting to continue with the Army, among personnel at junior enlisted ranks, the second most commonly cited reason for continuing to serve was the "Opportunity to Further my Education" (Vie et al., 2021).

The criteria for promotion, which as Chapter 2 noted plays a critical role in the military's up-or-out policies for remaining in the military, are important policy levers that can drive who seeks to learn what and at which rank. For example, as Chapter 2 described, the Army awards promotion points for completing military training and education and for civilian education and credentialing. Even when not codified in a points system, completing advanced civilian degrees or high achievement within certain military training or education courses, such as ranking in the top 10 percent of one's class as a distinguished graduate, can help make officers stand out as competitive at promotion boards (see Currie et al., 2012). Military members can also stand out as competitive based on training opportunities that can lead to career options in specialized units. For example, completing air assault training in the Army can create a potential opportunity to be part of Airborne units, and how members perform in these specific training courses can affect their prospects of being selected for more prestigious units.

Each Services' promotion policies also incentivize self-study of specific material or subject matter. For example, the Navy and Air Force administer occupational knowledge tests that weigh heavily when determining enlisted promotions. In addition, the Air Force administers a separate enlisted promotion test based on knowledge of topics such as Air Force history; Air Force programs, policies, and procedures; and theories of leadership (*Airman*, Secretary of the U.S. Air Force, 2021). Each of the Services considers physical fitness test scores in promotions, which may incentivize learning both the specific skills tested and learning about topics such as nutrition and weight management.

This policy also creates an expectation that as members advance in rank, they will be assigned to jobs with increased leadership responsibilities (*AR 614-100*, U.S. Department of Army, 2019). Recent large-scale job analyses by the Army Research Institute have confirmed that jobs held by higher-ranking enlisted members (E-7, E-8, and E-9) require leadership, management, and interpersonal skills to a greater extent than those at lower ranks (E-5 and E-6) (Royston & Amey, 2023). Specifically, while the Army views detail focus and stress tolerance as the most important attributes for successful performance of E-5 jobs, communication ability becomes increasingly important in E-6 and E-7 jobs, and leadership skills, such as sustaining a climate of trust and leading by example, become most important at the E-9 level (Royston & Amey, 2023). Large-scale job analyses for Army officers show a shift to emphasize communication to a greater extent as one progresses in rank. For officers, dependability and stress tolerance are viewed as the most important attribute for successful performance of Army O-1 and O-2 jobs, but this shifts such that communication ability becomes the most important attribute for successful performance of O-4, O-5, and O-6 jobs (Royston & Amey, 2023).

Although promotions entail greater emphasis on communication or leadership, not all military members are eager to "progress" from jobs that allow them to focus on technical skills such as flying aircraft (Robbert et al., 2018). Serving as a warrant officer, rather than a commissioned officer or enlisted member, provides a highly technical track with a defined duty set in some Services, but this technical track is only available for a small number of career fields (Novelly, 2024). This technical track also corresponds to a lower rate of pay than that offered for commissioned officers. For example, although the Air Force recently announced plans to implement a warrant officer track for cyber and information technology career fields, it opted not to implement a warrant officer track for pilots because of concern that the lower pay rate of warrant officers would lower pilot retention rates (Novelly, 2024).

Military service can—and often does—provide a solid base of competencies to pursue a second career, and a second career after service can create substantial motivation for enlistees to take advantage of opportunities for tuition assistance and other funded education benefits while still serving in the military. The military has implemented programs to tie specific military training to certifications in the civilian sector. For example, the Army designed its credentialing opportunities online program (Army Credentialing Opportunities: Army COOL, 2022) to facilitate smooth transitions to civilian employment by helping soldiers find information on certification and licenses that bridge to civilian positions. Additional examples of specific programs include SkillBridge and Career Path DECIDE, which are both tools provided by the DoD (DoD SkillBridge, 2023; Military OneSource, n.d.).

Nonetheless, many military jobs do not have direct analogs in the civilian sector. Because of the relatively short time many military members spend in the military, learners may be more motivated to participate in learning and development experiences when they can see how these experiences will transfer to civilian jobs. If done correctly, connecting military competencies to civilian jobs has the potential to increase motivation for, and the quality of, learning, and thus performance within the military—as well as improve the welfare of military members.

What are the competencies that will be needed in civilian jobs? As early as 2004, economists highlighted the evolution of competencies needed in the employment market (Levy & Murnane, 2004):

> Declining portions of the labor force are engaged in jobs that consist primarily of routine cognitive work and routine manual labor—the types of tasks that are easiest to program computers to do. Growing proportions of the nation's labor force are engaged in jobs that emphasize expert thinking or complex communication—tasks that computers cannot do (pp. 53–54).

In summary, the competencies traditionally considered necessary for only the highest paid professions, such as problem solving and leadership, are now increasingly in demand for a growing number of U.S. jobs (Autor, 2015), reflecting the move away from routine tasks in the U.S. workplace (Autor & Handel, 2013). There has also been a shift in the U.S. labor market from specific technical competencies to ones that are more general (Ransom & Phipps, 2017). Other ongoing research shows high-value competencies are often those cognitively intense competencies that span multiple contexts, such as programming or data analysis (Phipps, 2024). At the same time, economists have observed that urban, non-college workers are performing fewer skilled jobs than before (Autor, 2019), which has led to greater polarization in urban labor markets and a reduction in relative earnings for urban, non-college educated workers. The military is facing a similar challenge. Together, these shifts in lifelong continuous learning and the larger labor market may be important when military leaders consider how they frame military learning and development opportunities.

Military Learner Families: Juggling Learning and Other Demands

All military learners' professional and personal lives evolve over time in ways that can shape how individuals engage in learning opportunities. For example, as adults age, they may start to form and grow their own families. In fact, a recently published National Academies report on military families found that about 50 percent of military members are married and about 39 percent have children. More than 70 percent of children in military families are younger than age 11, and approximately 38 percent are age 5 or younger (National Academies, 2019). As such, the military learner population is comparable to the population of nontraditional learners in that they are balancing multiple demands including family, a job, and other personal and professional responsibilities, in addition to continuous learning obligations (Ford & Vignare, 2015).

A recent survey conducted by the Office of People Analytics found that a key predictor of military retention among active-duty members was spousal and family support (Office of People Analytics, 2023), which underscores the salience of these multiple demands. In fact, the 2021 Army Career Engagement survey found that the most commonly cited reasons for enlisted personnel and officers to leave the Army were the effects of deployments on family or personal relationships, the impact of Army life on the career of one's spouse or significant other, and the effects of Army life on family plans to have children (Vie et al., 2021).

For many military learners, self-efficacy—their belief that they can execute a task—will likely be a critical determinant of their willingness to engage in further learning opportunities and their persistence during learning. An individual's self-efficacy is even more pressing when faced with multiple demands and limited time. Furthermore, this may be increasingly true as many learning opportunities occur outside of the formal context, such as in an asynchronous online course (see Chapter 3), and the learner needs to actively designate time to engaging in learning opportunities. The value of making space for learning, given other demands, is an emerging area of research, and additional work is needed to better understand this in the military context (Lyndgaard & Kanfer, 2024).

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6
Technology-Enabled Learning

Throughout history, humans have employed various technologies to facilitate learning, from primitive cave paintings and 11th-century medical mannequins to modern flight simulators and anytime-anywhere digital learning. Technology comes in many forms, with no specific technology being greater than another; its utility derives from how well it can facilitate the design and development of instructional materials, enable a range of assessment activities across multitudes of constructs, and support management processes—such as tracking training assignments, issuing personnel qualifications, enabling complex exercises, recommending learning opportunities, or enabling readiness reporting. In other words, technology-enabled learning comes in many forms and can support a variety of stakeholders, from learners, teachers, and trainers to instructional designers, registrars, administrators, and military commanders. From a military perspective, these technologies, when employed effectively, can support more efficient, responsive, and transparent force generation and personnel readiness.

In this chapter, the committee refers to the breadth of technologies used for education, training, informal learning, instructional design, testing, and assessment as *technology-enabled learning*. Technology-enabled learning has been, and will continue to be, a critical investment for military stakeholders, even as the characteristics of those investments evolve to meet emerging requirements and to embrace the latest innovations. The rate at which these technologies mature makes it challenging for researchers and practitioners to use them effectively and in a timely manner. This is why the committee recommends a strategic ecosystem-based approach to manage evolving technologies affecting learning practices (see Chapter 8). By using a Modular Open Systems Approach (MOSA), which includes interoperable technology standards and constructs, technology stakeholders can more systematically pursue performance and practical outcomes, to include facilitating an evidenced-based evolutionary approach to acquiring, maintaining, and innovating their learning technologies at scale.

This chapter examines how technologies enhance aspects of learning, both within and beyond military contexts, and then discusses a variety of promising technology-enabled learning applications. While this is not a comprehensive review, the chapter is intended to guide a discussion of high-impact areas for future research and investments. Finally, the chapter discusses new paradigms for technology-enabled learning, including Learning Engineering and a Digital Learning Ecosystem approach. These concepts take a systems approach to optimizing technology-enabled learning over time, with an emphasis on streamlining the evaluation and integration of future innovations. They integrate different disciplines, systems, and infrastructure elements with the purported aim of optimizing learning outcomes at a greater scale and with more efficiency and responsiveness to change.

HOW TECHNOLOGY SUPPORTS LEARNING

A comprehensive exploration of technology-enabled learning forms and uses would require several books' worth of explanation, so rather than review all technologies, the committee instead highlights some well-established principles of learning to demonstrate the potential of effectively employed technologies. Specifically, in this section, the committee builds on the general principles of adult learning discussed in prior chapters to show how technologies can enhance them. The committee also draws from the principles of learning discussed in two National Academies reports, *How People Learn* (National Research Council, 2000) and *How People Learn II* (National Academies, 2018), particularly the properties required to drive skill acquisition.

Instructional Media Design

As discussed in Chapter 3, the design and delivery of instructional experiences significantly affect learning outcomes, including acquisition and transfer. They also influence affective factors, such as motivation, and practical factors, such as cost and throughput. In the context of technology-enabled learning, the committee specifically considers the design of multimedia instructional materials and the technological interfaces used to access them for delivery of learning content. *Multimedia* refers to the combination of words and pictures, whether written and vocalized or presented as images and videos (Mayer, 2008, 2009). Today, nearly all technology-enabled learning uses multimedia such as instructional videos, online courses, simulations, and technology-enhanced classrooms to facilitate content delivery. It is important to remember that the impact of learning relies on the quality of content. The technology used to deliver the content can either enhance or detract from that experience, depending on its design and alignment with learning objectives (Clark, 1983).

Well-designed multimedia instruction can accelerate learning and motivate engagement (Mayer, 2017). Conversely, poor designs can cause distraction, frustration, and lowered outcomes (Mayer, 2008, 2009; Sweller et al., 2019; van Merriënboer & Sweller, 2005). The principles for designing effective multimedia instruction have been well established. They begin with cognitive psychology tenets, such as the observation that people have a finite working memory capacity and that humans use two separate channels for processing auditory and visual information (Mariano, 2014). Researchers have extended these theories into practical methods and validated their impacts.

Two examples of well-established multimedia instructional principles are the cognitive load theory (Sweller et al., 1998; 2019) and cognitive theory of multimedia learning (Moreno & Mayer, 1999). Cognitive load theory recognizes that there are different types of cognitive load competing for an individual's limited mental resources and that effective media design should attempt to reduce extraneous load, such as those distracting visual features create, while supporting germane load, such as providing scaffolding (i.e., gradually removing learning support as students learn) to aid schema construction. Similarly, the cognitive theory of multimedia learning outlines empirically supported principles of instructional media design, including that humans learn best from the combination of words and images. Support for these theories has been provided in the empirical literature, particularly for captioned video for second-language acquisition (Montero-Perez et al., 2013) and use of personalized language in instructional technologies (Ginns et al., 2013).

A meta-meta-review of 29 reviews found significant and positive effects on learning from both cognitive-load theory and the cognitive theory of multimedia learning (Noetel et al., 2022), with the average moderate effect (effect size = 0.38). Certain principles had larger impacts; for instance, large effects were found for captioned video for second-language acquisition showed large effects (effect size = 0.99; Montero Perez et al., 2013) and personalization of language in instructional technologies (effect size = 0.62; Ginns et al., 2013).

In addition to cognitive psychology, another foundation for effective multimedia design comes from human factors and ergonomics. Learning experience design integrates principles of learning science and human-system interactions to enhance the usability, user experience, and aesthetics of technology-enabled learning interactions (Schatz, 2019; Schmidt et al., 2020). These qualities significantly affect outcomes across the range of interactive systems. General effects include increased effectiveness, efficiency, and satisfaction (Hornbæk & Law, 2007; Norman, 2004; Perrig et al., 2023; Thielsch et al., 2019). Such qualities are well studied in consumer technologies, but both learning experience design and more narrowly defined principles of usability, user experience, and aesthetics are under-evaluated in the technology-enabled learning domain (Lee & Hughes, 2019; Lu et al., 2022).

Limited use of learning experience design may help explain some of the variability between effective and ineffective technology-enabled learning experiences, especially when the information and pedagogical aspects of a given piece of multimedia instruction are otherwise well made. For example, a fully functional e-learning course might still produce suboptimal outcomes if it has a poorly designed user-interface (Miya & Govender, 2022) or if the supporting instructors are unable to use the technology effectively (Hodges et al., 2020).

While there is considerable evidence to inform effective instructional content design, there are many examples of poorly designed materials and interfaces, including in U.S. military contexts (Parker, 2020). Practical factors, such as “lack of time and resources, control over decision making, designer perceptions of a task, underlying philosophical beliefs, and designer expertise” (Parker, 2020, pp. 25-26; Dennen & Spector, 2007; Larson & Lockee, 2009; Tracey & Boling, 2014) can limit the ability of organizations to reliably produce quality instructional materials. As media grow in complexity, the pragmatic challenges of acquisition and maintenance grow.

Under optimal conditions, well-known principles of multimedia instructional design and learning experience design can produce medium to large positive results. However, practical limitations—such as faculty workload, low investment in usability, and budget constraints—temper these benefits. Research from multiple fields, such as medicine and population health, have all documented that practical barriers can create gaps between best research practices and implementation of the science. Importantly, these gaps can negatively impact return on investment (e.g., Bauer & Kirchner, 2020; Lobb & Colditz, 2013). Technology can enhance the effectiveness of instructional media, but only when design principles are followed; it cannot overcome a lack of investment or other pragmatic deficiencies. To help mitigate these issues, burgeoning research in implementation science encourages the practice of conducting a systematic examination of both the barriers and facilitators that may impact the uptake of evidence-based practices (Soicher et al., 2020).

Deliberate Practice, Active Learning, and Simulations

As discussed in Chapter 3, experience and practice are important components for building and sustaining expertise. However, simple task repetition is not sufficient. Practice activities tend to be most effective when structured and targeted. Examples of such frameworks include learning-by-doing (Dewey, 1938; Williams, 2017), experiential learning theory (Kolb, 1984), and deliberate practice (Ericsson et al., 1993; Hambrick et al., 2020).

Experiential learning theory creates an instructional framework around experiences that includes self-reflection, generalizing the experience, and experimenting with recently acquired knowledge and skills in new situations. A meta-analysis on experiential learning found that learning outcomes were significantly higher in classes using experiential learning pedagogies (effect size = 0.43), a medium size (Burch et al., 2019; see also Chapter 3).

For deliberate practice, there are well-established principles for its implementation, which have also been extended to military learning contexts (e.g., Williams, et al. 2008; Goldberg et al., 2018). Meta-analyses have found that deliberate practice methods can explain a portion of the variance associated with expertise. For instance, one meta-analysis found that deliberate practice accounted for 26 percent of the variance in performance for games, 21 percent for music, and 18 percent for sports, although only 4 percent for education (Macnamara et al., 2014). Another large-scale meta-analysis of studies across all learning outcomes found that deliberate practice has an average effect size 0.79 (Hattie, 2009; see also Waack, 2018, for a summary diagram of all the effect sizes), a large effect. While deliberate practice serves as a foundational theory applied to expertise-focused training strategies, Hambrick and others (2020) have found that expertise development is influenced by multiple factors beyond just practice intent. The authors argue for a more nuanced multifactorial model that includes a combination of elements such as cognitive abilities, personality traits, environmental factors, practice habits, and genetic talent. Unlike the singular focus on deliberate practice, the multifactorial view acknowledges that these factors interact to varying degrees, leading to differences in how individuals develop expertise in complex domains such as sports, music, and academic fields.

Although the implementation of deliberate practice and active learning does not require technology, certain tasks—such as those that are risky, costly, and complex—can greatly benefit from technology-enabled learning. For example, aircraft pilot training can include rare problems and unique scenarios that the trainee can practice in the simulator safely and relatively easily.

In addition to creating safer and less expensive practice environments, simulation-based training can provide additional scaffolding for experiential learning and deliberate practice. For example, a pilot-in-training struggling with aircraft landings can isolate that particular skill and focus on its refinement, rather than spending time in a real aircraft to take off, fly around, and then practice landing (Tuker, 2024). Simulations also allow the conditions of a situation, such as the weather conditions, to be varied, again enabling a more efficient approach to deliberate practice than could be achieved in real-world conditions.

Technology can also facilitate feedback delivery, which is an essential component of deliberate practice. Simulations offer a controlled environment for study that enables the easy collection of process and outcome data as well as video captures of performance. These data allow trainees and instructors to review trainees' performance, and groups of trainees can compare and discuss their performance on identical tasks. Furthermore, simulations can provide the trainees with cause-and-effect feedback almost immediately—when it is most effective for novice and early-journeyman learners (Wisniewski et al., 2020). Technology-enabled learning can also support robust after-action reviews, with debrief interfaces that allow learners and instructors to methodically review a deliberate practice event and emphasize discussion and reflection to stimulate the experiential learning abstraction process. A meta-analysis found that structured reviews following an experiential learning event led to a large effect size = 0.79 (Keiser & Arthur, 2021), which is largely credited to the alignment of data and visualizations aligned to learners and the representation of objective performance in digestible formats.

In addition to standard scenarios, simulations can incorporate productive failure situations, where learners can safely fail to explore the boundaries of their own capabilities and better prepare for future learning experiences (Darabi et al., 2018; Sinha & Kapur, 2021). Technology can also enhance these experiences by incorporating focused feedback and self-reflection to drive behavioral change on subsequent performance opportunities (Letelier, 2022).

This is particularly relevant for military contexts, where members can practice dangerous missions in relatively safe and repeatable technology-enabled learning environments to help hone skillsets and improve the likelihood of live-mission success.

For these reasons, analyses of simulation-based training consistently show positive effects. For example, a meta-analysis of 26 experiments involving aircraft pilot training demonstrated that integrating simulation-based practice with aircraft training consistently produced better outcomes than training without simulator use (Hays et al., 1992). Similarly, a meta-analysis of simulations used in higher-education contexts found an overall large effect of 0.85 when the technology use was combined with effective pedagogical scaffolding methods (Chernikova et al., 2020), and a recent review of simulation-based training for military nurses found that simulations can improve their taskwork and teamwork and help them prepare for complex and stressful life-threatening environments (Niu, 2022).

Today, instructional simulations for military applications come in countless shapes and sizes. At the lower-technology end of the spectrum, a simulation might involve a sand table that mimics real-world terrain and military figurines representing tactical forces. At the more technologically advanced end of the spectrum, large-scale military exercises might employ a combination of live, virtual, and constructive elements using automated computer-based agents. For example, this might involve real pilots in real aircraft fighting against computer-based adversaries and coordinating with teammates in an operations center who are seeing simulated content on their sensors and screens (Tran & Tran, 2022).

There is a rich literature about instructional considerations for simulations and advice for balancing their technological cost, which is often associated with their level of fidelity, against the desired learning outcomes. For example, a comprehensive study of U.S. Army training found that while these simulations produce impressive outcomes, their practical return on investment is sometimes poor because of over-investment in bells-and-whistles in lieu of sufficient investments in simulation pedagogy (Straus et al., 2019). Similarly, research on Australian Army M4 marksmanship training found that shifting some investments from whiz-bang technology features—such as unnecessary fidelity—to pedagogical aspects, including better analysis and feedback delivery, could improve the overall return on investment (Stephens & Temby, 2014).

In summary, military learning applications frequently use instructional simulations. However, simulators' ability to support learning outcomes lies not only in their technological sophistication but in their effective facilitation of learning principles, such as those embodied in the theories of experiential learning and deliberate practice. When sound learning principles are integrated into technology-enabled learning such as simulations, it is possible to achieve significant gains in learning.

Adaptive Learning

As discussed in Chapter 4, individual differences moderate learning outcomes. These differences include individual characteristics such as prior experiences, age, and motivations; short-term states such as stress or fatigue; and current behaviors such as engaging with distractions or attempting to game the system. Adaptive learning methods attempt to respond to these differences to improve outcomes such as achievement, efficiency, and engagement.

Adaptive instructional systems are computer-based systems that use artificial intelligence (AI) and user modeling to determine what to teach, when to teach it, and which methods of instruction to use. Adaptive instructional systems may adjust aspects of a learning experience, such as the topics covered or the instructional methods used, similar to how human tutors might adapt how they explain something based on interactions with their learners.

Adaptive instructional systems, which are usually partially or wholly automated to provide scale (Brusilovsky & Peylo, 2003), have been used in a variety of applied settings (Nye et al., 2015), and research has demonstrated their effectiveness across several application environments, including military domains (Sottilare et al., 2018). For example, a meta-analysis of one type of adaptive instructional system, called an intelligent tutor, showed that it improved learning compared with classroom teaching, reading texts, and other traditional learning methods, with effect sizes ranging from 0.09 to 0.76 (D'Mello & Graesser, 2023). Another meta-analysis examined AI-enabled adaptive tutors; it found that they have medium to large positive effects (0.70) compared to non-adaptive methods. A systematic literature review examining intelligent tutors with game-playing features found they improved student outcomes and increased student motivation and engagement (Ramadhan et al., 2024).

There is sizable variability across adaptive instructional systems results, in part because they are moderated by the curriculum, intervention duration, learner levels, subject domains, learner prior knowledge, assessment methodology, and comparison group. For example, a meta-analysis examining the effects of various parameters such as software and hardware features on adaptive instructional systems revealed diverse outcomes (Zheng, et al., 2022a), ranging from slightly negative (-0.009 slight negative effect for personalized learning suggestions) to notably positive (1.778 very large positive effect for personalized prompts). Another dramatic example is the Digital Tutor, used to teach information technology (IT) competencies to U.S. Naval personnel. It demonstrated huge effect sizes of 1.97 and 3.18 (Kulik & Fletcher, 2016), even when compared to experienced IT professionals. However, Digital Tutor cost approximately $50 million to produce and only covered half of the curriculum in the Naval IT course (Kulik & Fletcher, 2015). This highlights the need for formal ROI metrics aligned to intelligent tutoring implementation. (See Fletcher & Sottilare, 2014 for a discussion on cost analysis methods for adaptive instructional systems.)

Adaptive instructional systems take many forms. At the lower-technology end of the spectrum, a system might involve simple adaptive hypermedia that takes learners down different prescribed paths in response to their performance or personal characteristics such as age or learning preferences. For example, many U.S. military e-learning platforms use pretests to determine learners' incoming knowledge levels and skip certain course modules based on those test outcomes. At the higher-technology end of the spectrum, adaptive instructional systems may involve conversational agents that engage learners in a natural language dialogue. For example, AutoTutor simulates the dialogue of a human tutor along with ideal instructional strategies that facilitate active learning (Nye et al., 2014). A recent meta-analysis of AI-powered virtual conversational agent studies found an overall medium positive effect for them compared to non-AI adaptive instructional dialogue (Dai et al., 2024).

Adaptive instructional systems may be integrated into simulations, combining the impact of active learning and deliberate practice with the benefits of focused coaching and adaptivity (Schatz et al., 2012). For example, the U.S. Army showed significant improvement in transfer performance for U.S. Military Academy cadets learning combat lifesaving skills in a game-based environment through real-time learner modeling and feedback (Goldberg & Cannon-Bowers, 2015). The U.S. Air Force invested in the Predictive Performance Optimizer, an algorithm built into medical training mannequins to predict when nursing students need to retrain their cardiopulmonary resuscitation skills (Jastrzembski & Sanderson, 2019).

As the prior example also shows, adaptive instructional systems are not limited to traditional forms of educational knowledge acquisition. Adaptability can be built into physical training systems, such as medical mannequins or training ranges. It can be integrated into perception training systems (Fadde, 2009; Kellman, 2013), physical training systems targeting psychomotor development (Goldberg et al., 2018) or combined with human tutors to improve their efficiency and scale (Goldberg et al., 2020; Ritter et al., 2016). Adaptive algorithms are also integrated into popular commercial applications, such as Duolingo and Khan Academy, to facilitate engagement and systematic progress through the curriculum based on best practices of learning linked to spacing effects and interleaved practice (e.g., Sahana & Dissanayake, 2024).

In addition to responding to learners' traits and demonstrated performance, adaptive instructional systems can also adapt to learners' states. For example, adaptive instructional systems that build upon affective computing can respond to learners' emotions and their transitional properties, such as preventing a state of confusion from transitioning into a state of frustration (D'Mello & Graesser, 2012). Using such inputs such as mouse and keyboard behaviors, AI-enabled computer vision, eye tracking, heartrate monitors, and electroencephalograms, affective adaptive instructional systems can make inferences about relevant variables, such as a learner's level of confusion or boredom, and then adjust the learning experience accordingly (Calvo & D'Mello, 2010; Picard, 2000; Pourmirzaei et al., 2023; Rasheed & Wahid, 2023; Schmitz-Hübsch et al., 2022).

Some of the most sophisticated adaptive instructional systems combine these multiple elements and integrate behavioral, performance, and inferential-state data. For example, the U.S. Army has used its Generalized Intelligent Framework for Tutoring (Sottilare et al., 2012) to integrate virtual reality with complex adaptivity in dozens of concrete learning environments, including marksmanship training, team tutoring, and aircraft maintenance (Goldberg & Sinatra 2023). The Army is currently studying this framework in the context of competency-based experiential learning, with a strategy for monitoring performance and interaction longitudinally across scenarios to better infer proficiency and guide subsequent interactions to moderate learning progression. The Army is investigating this approach in squad battle drill and medical team training contexts, incorporating communication (Spain et al., 2022), computer vision (Vatral et al., 2022b), and performance in a physical-immersive adaptive simulation (Goldberg et al., 2021; Hernandez et al., 2022; Presnall et al., 2024).

Projects such as the Personal Assistant for Lifelong Learning and the Generalized Intelligent Framework for Tutoring show promise, and using adaptive instructional systems aligns with various U.S. military modernization strategies, for example, the Navy's *Ready Relevant Learning* and the *Army Learning Concept for 2030-2040*. Despite this, adaptive instructional systems have yet to be implemented widely outside of experimental settings (Goldberg & Sinatra, 2023), in part because of the cost to develop and implement these systems (D'Mello & Graesser, 2023). Even if the total ROI is favorable, in terms of monetary and time resources, the U.S. military has been reluctant to make those upfront investments (e.g., Fletcher, 2017; Robbins, 2016). To address barriers to adoption, researchers are exploring reusable and generalizable tools to enable building modular adaptive instructional systems platforms at scale.

Another limitation that links with the cost issue is that most adaptive instructional systems have a narrow scope regarding the topics they cover. For example, a hypothetical adaptive instructional system might focus on freshman algebra, but if a particular student struggles with reading comprehension, the system may not be equipped to diagnose or respond appropriately. Hence, while the impacts of well-defined adaptative instructional systems are substantial, they are diluted when viewed in the context of someone's broad capabilities (across topics) and learning journey (over time).

The scope and costing issues are further exacerbated when data stored within a particular system is proprietary or written in a developer-specific format that cannot be interpreted by other systems (e.g., Goodell, Hampton, Tong, & Schatz, 2022). This makes it difficult to highlight linkages across topics (e.g., connecting algebra and reading comprehension) and to support longitudinal learning trajectories, where a person's learning is supported by adaptive automation over a longer period time. Research suggests that understanding and activating a learner's prior knowledge (Simonsmeier et al., 2022) as well as connecting learning to individuals' existing mental schemas (e.g., Brod & Shing, 2019) are strong predictors of learning. This implies that better connectivity of content as well as learner data across platforms would provide benefits.

In summary, while adaptive instructional systems show positive effects, and in some cases massive improvements over other methods, their use is often limited by practical factors such as development and maintenance costs, as well as by the scope of content and data available to any individual system.

Data-Informed Assessments and Interventions

As will be discussed in Chapter 7, assessment data play a critical role in understanding and improving learning outcomes. Summative assessments provide valuable evidence to guide instructional decisions and measure proficiencies, and formative assessments paired with effective feedback are among the most powerful ways to enhance achievement (e.g., Ainsworth & Viegut, 2006; Hattie & Timperley, 2007). Considerable work goes into administering quality assessments and modeling the target competencies and constructs aligned with those measures, evaluating assessment results, and acting in response to assessment findings. Technology can support each part of this process.

For test administration, computer adaptive testing has transformed administration of conventional assessments into more effective and efficient measures. Adaptive tests present the test taker with a series of items, each with a high level of uncertainty regarding the test taker's performance. As test takers respond to an item, the uncertainty falls, reflecting the fact that someone who answers correctly is more likely to have mastered that topic, while someone who answers incorrectly is less likely to have mastered the topic. Computer adaptive testing offers several benefits over nonadaptive methods, such as mitigating the effect of guessing, decreasing bias based on individual differences, and reducing frustration in lower performers as well as boredom in higher performers. Computer adaptive testing also substantially reduces the time required for testing by 50 percent or more without sacrificing measurement quality (Weiss & Sahin, 2024). The U.S. military was an early adopter of computer adaptive testing in the ASVAB, incorporating it around 1990 and still using it today (Pommerich et al., 2009).

In addition to supporting assessment delivery, digital technologies can improve the evaluation of assessment results. In particular, the fields of educational data mining and learning analytics use advanced statistical methods to find actionable insights in learning-relevant data. Educational data mining emerged around 2005, and learning analytics followed around 2011 (Baker & Inventado, 2014). Today, these fields have largely converged (Lemay, Baek, & Doleck, 2021). In both cases, data come from different sources, including tests and quizzes; interaction behaviors, such as mouse and keyboard clicks, forum messages, and administrative information about a course; demographic data about individuals; and other personal or contextual factors. By using data mining, other statistical techniques, and various AI methods, these technologies identify meaningful information that may apply to an individual learner, to a collective group such as a class, or to institutional considerations such as an entire program of study (Siemens & Long, 2011).

Examples of applied educational data mining and learning analytics include presenting dashboards to learners to increase their motivation and engagement (Tepgeç & Ifenthaler, 2022); nudging behaviors, particularly in online contexts, to increase engagement (Brown et al., 2024); and identifying at-risk higher-education students and then proactively intervening to increase retention (Shafiq et al., 2022; Wong & Li, 2020). These analytical algorithms can also inform adaptive learning when incorporated into adaptive instructional systems technologies (D'Mello & Graesser, 2023), including at large scales such as in massive open online courses (Yu, 2021). Educational data mining and learning analytics can also inform scholarly understanding, such as by providing generalizable insights into students' learning rates and the impact of repeated practice on mastery (Koedinger et al., 2023). For example, recent research examining a mixed-effects growth model across 27 distinct data sets has shown that students' learning rates do not differ as much as previously hypothesized, with prior knowledge serving as the primary moderator of where learning within a domain initiates and the number of practice opportunities serving as a predictive variable of mastery outcomes (Koedinger et al., 2023). The researchers of this study note that the results may not generalize across all learning contexts that provide favorable learning conditions, and that there may be limitations in the multilevel data or measurement model that might explain the near constant student learning rate (Rights & Sterba, 2023).

As data streams grow richer and analytical techniques advance, the potential for data-driven optimization of learning processes increases. Areas of investigation include stealth assessment, which gleans measures of competencies such as grit and problem solving through performance observed in an alternative activity, such as playing a videogame (Shute et al., 2021). Multimodal learning analytics is a technique that combines data from diverse sources, such as from log files, body sensors, eye tracking, speech recognition, and computer vision sensing. Similarly, inferential analytics aims to develop robust models for reasoning about variables such as motivation, engagement, and cognitive load from observable signals (Baker et al., 2021). To this end, learning environment instrumentation is critical.

Data instrumentation needs to be explicitly addressed in the design of future learning environments and to account for the challenges and costs associated with the implementation of adaptive learning, as outlined above. Emerging technologies, described further down in this chapter, are dependent on well established data strategies that focus on strategic collection and fusion of diverse data streams to support robust machine learning and to train AI derived models that support objective assessment of performance. Rather than collecting data for the sake of it, there should be an emphasis on the problems one aims to solve with technology and the type of data required. A goal is to establish extensible techniques that move away from data mining exploration and to instantiate repeatable methods to reliably capture and make use of data across disparate domains and learning contexts.

Beyond a strategy to collect multimodal data, effective utilization for AI-driven training hinges on its structure and organization. This entails enforcing consistency in data formats, applying accurate labels across data points on a temporal timeline that are rich in context, and transforming the data into variables (e.g., transforming electrocardiogram raw data into inter-beat interval metrics and heart rate variability values) and feature sets suitable for AI algorithms (e.g., transforming high-definition video into distance-, angle-, and time-associated features of movement within an environment; Vatral et al., 2022).

In the context of immersive learning environments leveraging simulation and mixed reality tools and methods, the fusion and time-synchronization of data are pivotal. This includes alignment of data sources across simulation telemetry, cameras, microphones, and wearable sensors to establish a synchronized data log associated within a learning context. This structured data can then be used to train various AI algorithms, such as Convolutional Neural Networks (CNNs; Li, Liu, Yang, Peng & Zhou, 2021), Recurrent Neural Networks (RNNs; Namoun & Alshanqiti, 2020), and Long Short-Term Memory networks (LSTMs; Lindemann, Muller, Vietz, Jazdi & Weyrich, 2021). CNNs, RNNs, and LSTMs are all types of deep learning architectures, but they differ in their structure and application. CNNs excel at processing spatial data like images, leveraging convolutional filters to detect local patterns and hierarchies of features (Li et al., 2021). RNNs are designed for sequential data such as text or time series, employing recurrent connections to maintain an internal state that captures temporal dependencies between elements (Namoun, 2020). LSTMs, a specialized form of RNN, address the vanishing gradient problem often encountered in traditional RNNs by introducing memory cells with gating mechanisms (Lindemann et al., 2021). These gates regulate the flow of information, allowing LSTMs to effectively learn and remember long-term dependencies in sequences, making them suitable for tasks like natural language processing and speech recognition where long-range context is crucial.

These data are only useful, however, if they measure meaningful factors. As Chapter 7 will highlight, assessments are most effective when they measure outcomes, not outputs, and align well with the variables of interest, such as learner performance, rather than poor proxy measures, such as time spent in training. In learning contexts, this often translates to using outcomes-based training and education (U.S. Joint Instruction on Officer Professional Military Education Policy, CJCSI 1800.01F, 2020; DoD Instruction 1322.35, U.S. DoD, 2022) and competency-based learning (Air Force Handbook 36-2647, U.S. Department of the Air Force, 2022). These approaches define desirable performance, often across knowledge, skill, behaviors, and other such factors as motives and traits (Stafford, 2019).

Competency-based approaches to assessment complement well-established learning methods, including mastery learning (Bloom, 1974), and competency-based approaches facilitate such benefits as improved learning outcomes (Chen et al., 2022; Mallillin et al., 2021), greater retention and graduation rates (Blankenberger et al., 2024), and increased transfer from learning contexts to on-the-job performance (Malhotra et al., 2023; Mursalin et al., 2024). Perhaps even more promising, a competency-based approach to assessment can promote interoperability, enabling different instructional programs, institutions, and workplaces to align their offerings to published competency frameworks and accurately compare their offerings. As a result, this can reveal insights that guide collective initiatives, such as curricular gaps in a particular program of study (Nazeha et al., 2020).

Self-Directed and Social Learning

As discussed in Chapter 3, self-directed learning (Hase & Kenyon, 2000) and social learning (Siemens, 2005) are growing in importance as the emphasis on career-long learning expands and thanks to the increasing availability of information and communication technology that facilitates these learning methods conveniently, efficiently, and at a large scale. For example, e-learning and social-collaborative platforms enable instruction to be disaggregated from specific locations and schedules, with meta-analyses of e-learning showing modest benefits over traditional, in-person classroom learning (an average effect size of 1.56, Martin et al., 2022) and even greater impacts when paired with collaborative methods (effect size of 0.25, U.S. Department of Education, 2010).

Tools such as learning experience platforms and massive open online courses (or MOOCs) can offer additional features, providing open access to course materials and expert-guided learning at massive scales. Similarly, crowdsourced social platforms such as YouTube, Wikipedia, and Reddit can help individuals learn from one another, albeit often with conflicting, incomplete, or biased information that individuals are required to learn how to evaluate, synthesize, or discard, as appropriate (Dron & Anderson, 2014).

In addition to supporting traditional approaches more flexibly, information and communication technology facilitates new paradigms, including just-in-time learning and microlearning. Just-in-time learning is a type of informal learning where individuals access instruction on-demand, often gaining just enough knowledge to perform some task in an applied context, quickly and in-the-moment (Brandenburg & Ellinger, 2003; Riel, 2000). Microlearning occurs when instructional or informational content is delivered in bite-sized pieces (Lee, 2023). These forms of informal learning are often delivered via mobile technologies, including mobile phones, tablets, and laptops. Mobile learning, in its many forms, has demonstrated broad, positive effects, with one meta-analysis finding an average effect of 0.85 (Talan, 2020). Mobile learning works effectively in low-bandwidth contexts, for example by using basic text-messaging (Jordan, 2023). Where feasible, mobile learning can also take advantage of the higher-bandwidth, sophisticated technologies found in modern smartphones, including Global Positioning System capabilities, accelerometers, gyroscopes, and proximity sensors that enable communication with nearby physical beacons.

A person's metacognitive abilities, sense of agency, and self-efficacy strongly influence effective self-directed learning (Blaschke, 2018). In other words, learners need to be aware of their own capability gaps and have the motivation, ability, confidence, and self-reflective clarity to seek out appropriate content and experiences to close those gaps, particularly in unfamiliar and unanticipated situations (Hase & Keynon, 2007). Hence, one challenge for systems designed to facilitate self-directed learning is to incorporate appropriate metacognitive scaffolding, concept linking, and feedback (e.g., Lai et al., 2022; Lajoie, 2008; Tur et al., 2022; Vaičiūnienė & Kazlauskienė, 2023).

Even if someone possesses such personal capacities or is adequately supported through instructional designs, they may struggle to find the right resources in a timely manner if not also supported by technology. Imagine the challenge of finding information online without the aid of a search engine, the difficulty evaluating social media posts without their digital context, or the frustration of synthesizing ideas when each piece of content is blocked by an individual paywall.

These issues affected online learning during its early days, as educators tried to produce shareable learning objects that ultimately lacked reusability, accessibility, and discoverability. In other words, the materials were too specific to have broad applicability, people could not readily reach the content they needed, and individuals struggled to find available resources because content was locked away in different systems and organized using various categorization schemes (e.g., for a summary see, Nkuyubwatsi, 2016, pp. 24–54).

These issues have been somewhat mitigated by the Open Educational Resources (OER) movement, advances in semantic technologies that enable contextualizing and inter-linking of information based on meaning, and improved searching approaches, such as context and collaborative filtering. Today, search and recommendation algorithms use semantic values, such as the relationship between the words in a search query, someone's physical location, and search history, to help individuals more easily find and access the content they want, when and how they need it.

Nonetheless, discoverability—how well a person can efficiently find what they are looking for—remains challenging (Somerville & Conrad, 2013). It is affected by technology design, including usability and user experience design, as well as by back-end technology infrastructure. Although many advancements have been made, these infrastructure issues still create limitations, particularly for cross-platform systems in which different systems need to work together. Issues include ineffective filtering and discoverability of massive content repositories, lack of robust learner modeling to support cross-platform personalization, and fragmentation across disparate platforms and content sources resulting from a lack of technical interoperability standards.

Emerging infrastructure advancements show promise in addressing these challenges, as discussed in more detail in the Digital Learning Ecosystem section below. Briefly, these include repositories and registries that facilitate semantic organization, metadata standards that articulate descriptive and semantic features in broadly interpretable ways, and shareable user profiles that capture contextual and longitudinal data show promise in addressing these challenges (Goodell, et al., 2023a; Katz & Hong, 2024).

In summary, while self-directed and social learning models enabled by technology show promise for supporting lifelong and continuous learning needs, there are still limitations with existing systems. Without addressing these shortcomings, the potential of technology to facilitate individual and social self-regulated learning at scale over entire careers and lifetimes remains constrained. Technological support is needed to help learners find the right “signals in the noise” of so much information. Simply providing open access to materials is insufficient on its own; support for foraging and heutagogical and metacognitive scaffolding are also required.

EMERGING TECHNOLOGIES

Rapid innovation is occurring across technology-enabled learning sectors. Reporting on all promising technologies would be unrealistic in this report; instead, this section covers several areas that show promise for research, development, and potential military uses—especially for developing and maintaining the core competencies military members use in dangerous and resource-intensive environments (e.g., *TRADOC Pamphlet 525-8-2*, U.S. Department of the Army, 2024).

The categories included in this section roughly align with the technology-enabled learning approaches described above. The advancements covered here include the following:

1. Automated multimedia creation through generative AI;
2. New ways of supporting deliberate practice through extended reality, immersion, and human-AI teams;
3. Adaptive learning via digital twins and generative AI-enabled conversational agents that use large language models to support assessment, coaching, and content creation;
4. Learning analytics innovations that leverage stealth assessment, multimodal data, and hybrid modeling techniques, as well as emerging ways of supporting competency-based approaches through technology;
5. New ways of supporting self-directed learning through generative AI; and
6. Neurophysiological tools, including sensing and stimulation neurotechnologies and emerging research at the brain chemistry level.

These new capabilities have the potential to improve learning, but because of their novelty, there is limited evidence regarding their effects on learning. Further, the following technologies are maturing at a rate that could make current capabilities obsolete within a 12-month timeframe (World Economic Forum, 2023). The rate at which these technologies mature makes it challenging for research and practitioner communities to use them effectively and in a timely manner. This is why we later emphasize the need for a strategic ecosystem-based approach to manage the adoption of evolving technologies impacting learning practices.

Generative AI

Generative AI uses robust models designed to generate synthetic data that closely reflects real-world data and interaction (Bandi et al., 2023). It employs deep learning models and algorithms to generate synthetic data outputs, such as text, images, simulations, and/or predictions, based on the data on which it has been trained. In the context of adult learning in the military, generative AI can significantly enhance training and education by enabling scalable, personalized learning experiences as well as supporting and simplifying laborious aspects of instructional design and assessment. Relying on large datasets of input data, these tools can piece together increasingly realistic text, images, sounds, and videos that can be difficult to distinguish from human-generated content. In the context of learning technologies, generative AI can create opportunities to reduce the human workload, especially in regard to providing tailored instruction and materials to learners at scale.

Generative AI for Content Creation

The power of generative AI lies in its ability to rapidly generate high-quality, coherent, and contextually relevant learning materials customized to learner needs at scale (Kasneci et al., 2023). In the realm of scenario-based training for military learners, these technologies can affect the way the military develops and deploys immersive exercises. By leveraging vast knowledge bases and the advanced natural language processing capabilities of large language models (e.g., Generative Pre-trained Transformer models built to mimic human interaction via transformer neural networks), scenario developers can generate realistic and contextually relevant narratives, character dialogues, and situational events that align with specific learning objectives and operational domains (Riedl & Young, 2010).

Beyond narrative design, generative AI can be integrated with game engines and virtual environments to create dynamic and adaptive scenarios that enable experiential learning through behavioral actions and decisions in real time (Kumaran, et al., 2023). This may include branching narratives, rapid adjustments to character behaviors, and the introduction of new elements based on learners' inputs, allowing learners to explore multiple paths and encounter diverse challenges within a single scenario. Such adaptability can enhance the effectiveness and engagement of learning experiences, fostering critical thinking, decision-making, and problem-solving skills (Mao et al., 2022).

Advanced AI can also streamline the creation, scheduling, and delivery of supplementary learning materials, such as briefings, debriefs and after-action reviews, additional practice sessions, and assessment tools (e.g., in-lesson quizzes), that complement and reinforce scenario-based training. These materials can be tailored to individual learners' needs, strengths, and weaknesses, providing personalized feedback and guidance to enhance knowledge retention and skill acquisition (Kadaruddin, 2023). The same functionality can be implemented to support the creation and refinement of adaptive instructional systems materials that drive personalized knowledge acquisition through focused content and assessment practices aligned to individualized learner needs (Kong & Yang, 2024).

These capabilities have the potential to significantly augment the roles and functions of curriculum and instructional system designers. While the capacity of generative AI and large language models in streamlining scenario creation and delivery is immense, it is crucial to address potential challenges and limitations (Song et al., 2024). Ensuring the accuracy, cultural sensitivity, and ethical integrity of the generated content is paramount, as scenarios in military contexts can have significant real-world implications. Collaborations between subject matter experts, instructional designers, and AI researchers will be essential to develop robust quality control mechanisms and governance frameworks. Recognizing this, the DoD adopted specific ethical principles for the use of AI in 2020 (*DOPSR Case # 20-S-1275*, U.S. DoD, 2020) and signed the Responsible AI Toolkit in June of 2022. Moving forward, it will also be imperative to review and update various job responsibilities, set and assign quality control methods, and establish troubleshooting processes. This can ensure that those engaged with AI capabilities have the necessary knowledge and skillsets to implement the technology appropriately, establish boundary parameters for models and monitor the quality of outputs, and build an understanding of the inner modeling mechanisms to address any errors or issues with outputs (i.e., minimize AI's "blackbox" functioning).

Generative AI and Self-Directed Learning

The military recognizes self-development as a vital domain for learning that supports broader learning objectives outside of their primary job function. When considering generative AI and self-directed learning, large language models can act as intelligent assistants, guiding learners through the process of identifying, curating, and synthesizing information from diverse sources. By engaging in natural language dialogues, learners can articulate their learning objectives. The large language model can suggest relevant materials, provide summaries, and offer contextual insights, streamlining the information-seeking process and acting as a pseudo-tutor. In this context, large language models provide an interesting capacity to establish tutor-defined agents through prompt engineering that parameterizes how a large language model manages inputs and structures outputs. These technologies are also well-suited to support SocraticAI methods, a branch of AI that focuses on generating questions and prompts to stimulate critical thinking and knowledge construction (Al-Hossami et al., 2023; Lara & Deckers, 2020). When paired with large language models, systems can engage learners in Socratic dialogues, posing thought-provoking questions, challenging assumptions, and providing feedback that encourages learners to delve deeper into a topic, explore multiple perspectives, and construct their own understanding (Gregorcic & Pendrill, 2023).

When considering self-directed learning within this collaborative context, these technological paradigms provide a form of augmented intelligence (i.e., using AI to enhance and augment human capability rather than replace or replicate it; Yilmaz & Yilmaz, 2023). With a focus on self-regulated settings and metacognitive support, research is required to objectively model the role generative AI can play in facilitating foundational learning processes. This requires research to explore direct extensions to foundational theoretical frameworks associated with self-regulated learning and metacognition. As AI systems become more sophisticated in their ability to engage learners in adaptive dialogues, generate personalized content, and provide real-time feedback, it is imperative to investigate how these capabilities can be integrated with established theories of self-regulation (Roll & Winne, 2015), metacognition (Lajoie, 2008; Lajoie et al., 2023), and constructivist learning (Vogel-Walcutt et al., 2011).

Empirical studies can model and objectively evaluate AI-supported interactions on learners' goal-setting processes, self-monitoring abilities, and metacognitive strategies. In addition, future research could explore how generative AI can scaffold learners' knowledge construction, enabling them to actively build upon their existing mental models and integrate new information more effectively. By bridging the gap between cutting-edge AI technologies and well-established learning theories, researchers can develop a comprehensive understanding of how to optimize the use of augmented intelligence in fostering self-directed, self-regulated, and meaningful learning experiences for individuals across various domains and educational contexts.

Extended Reality

Extended reality represents a spectrum of immersive technologies, including virtual reality, augmented reality, and mixed reality. Recent technological advancements and cost reductions have led to increased use of extended reality in learning scenarios. For example, head-mounted extended reality-powered displays create the possibility of fully immersive training from a spatial and visual sense (Tuker, 2024), allowing users to see the full picture of an operational environment and the tasks and competencies they are attempting to learn. While there is evidence of effectiveness for current commercial tools and methods (e.g., Kaplan et al., 2021, Howard, Gutworth, & Jacobs, 2021; Howard, & Gutworth, 2020; Howard, & Davis 2023), and significant research investments in this area continue, developers are only beginning to explore applications in spatial computing. Experimental extended reality technologies have the potential to alter the way people work and interface with their digital content. In addition, head-mounted displays are collecting more extensive data. When combined with physiological sensors to measure pupil dilation, heartrate, skin conductance, and even brainwave activity, these data can enable the development of increasingly sophisticated systems capable of combining real-time analysis of performance data and potential objective measures of learning.

Spatial Computing

Spatial computing within extended reality is a transformative blend of the physical and digital realms, enabling real-time interaction between devices, software, and the environment's geometry (Balakrishnan et al., 2021). This advance has the potential to significantly enhance extended reality capabilities, facilitating more natural interactions between users and digitally integrated objects within their actual surroundings (Israel & Scoble, 2016). Particularly in high-stakes areas such as military training, spatial computing can enhance simulation systems, offering trainees precise, context-specific information.

A key benefit of spatial computing in extended reality-based training is the boost it provides in situational awareness. For military applications, where accurate environmental comprehension can critically affect outcomes, spatial computing allows for a fluid integration of real and virtual elements. This seamless interaction supports intricate training scenarios that respond dynamically to the trainee's actions, offering instantaneous feedback and adaptable training modifications (Balakrishnan et al., 2021). Thus, spatial computing has the potential to enrich the training interaction space while quickening the learning process, delivering immersive experiences that replicate real-world conditions.

In addition, spatial computing facilitates creating enduring augmented reality experiences (Mystakidis, 2022). Virtual components can anchor to specific physical locales, maintaining consistency across various sessions and users. This feature is invaluable for collaborative training operations involving multiple participants, possibly spread across different geographic locations, who can engage with identical virtual objects or scenarios as if they were co-located. This capability enhances team collaboration and communication, while ensuring a uniform training environment that can be implemented on a broad scale, assuring consistent quality of training irrespective of location (Koumpouros, 2024). The integration of spatial computing in extended reality has the potential to provide learning environments that are more interactive, immersive, and efficacious to military-oriented learning objectives and contemporary operational contexts.

Volumetric Video in Extended Reality

Volumetric video represents an exciting extension of extended reality by capturing three-dimensional spaces, such as individuals or objects, from multiple angles with an array of cameras, and converting these captures into fully navigable three-dimensional (3D) models (Zerman et al., 2021). Its integration into extended reality training platforms is particularly promising for fields that demand high interactivity and spatial awareness (Goldberg & Cannon-Bowers, 2015).

This technology provides high fidelity and interactivity essential in high-stakes settings. Trainees can engage with lifelike 3D models of human actors and environments from any perspective, offering a level of presence and immersion unattainable with traditional flat videos or two-dimensional graphics. Such realism serves to narrow the gap between simulated training environments and real-world challenges, equipping learners with practical experience reflective of actual scenarios they might encounter. There have been promising early results in the medical domain (Hackett et al., 2022), with many extensions and advanced use cases yet to be explored.

Moreover, volumetric video significantly benefits collaborative training initiatives, allowing participants from various locations to simultaneously engage with the same lifelike scenarios (Li et al., 2019; Sasikumar et al., 2021). This technology not only elevates educational outcomes by providing intricate visual context, but also enhances the consistency of training quality regardless of geographic disparities. By incorporating volumetric video into extended reality training modules, organizations can deliver more intricate, captivating, and efficient training solutions that exploit the full spectrum of contemporary visual technology. This advance has the potential to revolutionize professional training in complex and critical skill areas, setting a new standard for educational excellence.

Multimodal Immersion in Extended Reality

Multimodal immersion in extended reality combines multiple sensory feedback mechanisms to create deeply immersive training environments (Rakkolainen et al., 2021). By leveraging the full range of sensory experience, information can be encoded more deeply and retrieval strength improved by increasing the connective nodes of information (Cadet & Chainay, 2020). This comprehensive sensory engagement is crucial for scenarios where high-fidelity realism is paramount, such as military, medical, or hazardous material handling type domains.

The integration of haptics in extended reality training systems allows participants to see, hear, and feel the environment around them. Advanced haptic technologies, such as gloves or suits, can simulate the weight, texture, and resistance of virtual objects, delivering physical feedback that mimics real-world interactions. This tactile information is essential for tasks requiring fine motor skills and enhances the trainee's dexterity and precision (Kaplan et al, 2021; Overtoom et al., 2019). For example, haptic feedback can mimic the recoil of a weapon, which can significantly improve the accuracy and realism of the training module.

While haptics offers potential to enhance the realism of extended reality environments, its widespread adoption faces several limitations. One of the primary challenges is the cost and complexity of developing sophisticated haptic feedback systems. Providing detailed and realistic tactical feedback often requires sophisticated hardware and software components, yet intricate variations in texture, resistance, and temperature are lacking the fidelity to create a truly immersive experience (Darken et al., 2022).

Olfactory technology, though less developed, offers unique benefits by adding a layer of realism through scents. The ability to simulate smells can dramatically enhance the realism of a scenario, such as the smell of smoke in fire evacuation drills or the odor of diesel in a military setting. In theory, engaging the sense of smell can improve immersion and enhance memory retention and recall, as scents are strongly linked to memory processing in the brain. However, empirical results are limited in determining the training impact of simulating malodors in a training environment (Kent et al., 2016; Pike, 2018).

Together, these multimodal interactions in extended reality environments can dramatically increase the effectiveness of training programs. They enable a level of realism that prepares individuals for real-world experiences in a safe, controlled, and repeatable manner. This full-spectrum immersion can significantly enhance decision-making skills, situational awareness, and operational preparedness, potentially transforming how professionals are trained across various disciplines. With these benefits in mind, it is important to consider potential negative impacts from these emerging capabilities. Additional research is required to objectively evaluate desensitization resulting from highly immersive training interactions. While there is substantial evidence in the literature highlighting benefits of exposure training on stress management (Mouloua et al., 2023) and exposure therapy on post-traumatic stress (Rizzo et al., 2024), there are no explicit studies that measure the transfer effects where tasks are performed in highly dangerous contexts.

Additionally, data instrumentation and data management for learning analytics within these highly immersive environments cannot be ignored. While spatial computing environments and multi-modal immersive interfaces can drastically enhance the fidelity of military aligned training scenarios, leveraging the data streams available within this type of infrastructure is necessary to manage objective performance evaluations of the competencies these enhanced environments target. This will necessitate an exploration of new techniques that apply spatial data and multi-modal interaction to create domain models that target objective performance evaluations across affective, behavioral, and cognitive performance factors. These specific goals are further discussed below in the subsection on innovations in measurement and assessment.

Immersion Walls

Immersion walls, such as video walls comprising multiple displays operating as one, and massive projection environments (Kavakli & Cremona, 2022), offer an innovative approach to enhancing military team training. By creating highly realistic and immersive environments that span entire rooms or walls, trainees can experience simulated scenarios with unprecedented levels of fidelity and realism. Volumetric video, which captures footage of real-world scenes and actors, can be integrated seamlessly into these immersive displays, enabling trainees to interact with lifelike virtual environments and characters in expansive settings (Helzle, 2023).

The emergent potential of these technologies lies in their ability to facilitate team-based exercises, fostering collaboration, communication, and coordination among multiple learners simultaneously (Sottilare et al., 2018). With a shared, highly immersive environment, team members can practice working together in realistic contexts, developing crucial teamwork skills, situational awareness, and decision-making abilities. This is particularly valuable in preparing for complex operations that require seamless coordination among various units and specialties.

While the peer-reviewed literature discussing these technologies applied in a military learning context is limited, several companies and industry partners market technologies of this nature directly to military organizations for procurement and acquisition. This calls for objective research to determine the best practices for leveraging immersion wall technology, the specific competencies and behaviors that these large collaborative interaction spaces can target and establishing appropriate metrics on presence and immersion to determine what effect they have on retention and transfer of targeted behaviors to live environments. This involves determining the extensibility of these technologies to support collective learning opportunities and to establish team tasks and structures best suited for these interaction spaces. In addition to training effectiveness-oriented research, it is important to address return-on-investment questions as well. This involves establishing a strategy to compare contemporary novel techniques against legacy best-in-practice tools for an established domain with variables aligned to performance variance, savings in time, and cost of implementation.

Human-AI Teaming

As technology grows in complexity and scope of capability, humans are relying increasingly on partnerships with machines, pushing low-level, repeatable, simple tasks to automated processes while providing oversight and direction. The human-machine teaming aspect is becoming increasingly important to understand, not only for learning but for the design of new technologies. This evolution is driven by the rapid advancement of AI and robotics, which requires new training paradigms where human skills are integrated seamlessly with machine capabilities. In military contexts, this means preparing personnel to effectively partner with intelligent systems, from autonomous vehicles to AI-driven decision support tools (see Box 6-1).

BOX 6-1

Human-Autonomy Teams in the Military[a]

In recent years, there has been an emergence in the area of human-autonomy teams, which are defined as humans and autonomous agents working together as teammates to accomplish shared goals (O'Neill et al., 2022). The inclusion of autonomous agents or robots in the military is not new (Cao et al., 2022). For example, robots are used in a wide range of military applications including artillery support, rescue operations, logistics support, explosive disarming, and monitoring (Zhao & Wang, 2022). However, recent advances make it increasingly likely that autonomous agents will not only function as a technical tool used by teams of humans, but also serve as a full-fledged team member (McNeese et al., 2023). While more research has been conducted recently (e.g., Cooke et al., 2020; McNeese et al., 2018), this area of research is just beginning, and gaps still remain in the literature. For example, many of the underlying theoretical frameworks of teams have been developed based on human-human teaming. More research is needed to better understand how adult learning on autonomous team configurations may be impacted, or how "human" factors—such as cooperation and psychological safety—can be fostered alongside autonomous agents.

[a] *This section draws from an expert review commissioned by the committee (Babiloni & Borghini, 2024).*

Despite similarities, training human-AI teams is different from training human-human teams (National Academies, 2022). Future training programs ought to emphasize cognitive flexibility, situational awareness, and decision making in environments where humans and machines collaborate (Stowers, et al., 2021). These programs can teach personnel not only how to use machines as tools but also how to interpret and trust machine-based inputs. This includes understanding the limitations and strengths of AI partners to mitigate risks associated with over-reliance on automation (Seeber et al., 2020). For example, trainees need to learn when to override automated systems based on their judgment and on situational nuances that the AI has not seen in its training data sets.

Replicating these complex systems and relationships accurately in simulation environments is crucial. Simulations ought to incorporate realistic AI behaviors and respond dynamically to human inputs in a way that mirrors real operational systems. This involves using surrogate sensors and algorithms to simulate AI decision-making processes, ensuring that AI entities behave in ways consistent with their real-world counterparts. For example, AI agents in a training simulation would be able to execute tasks, provide situational analysis, and adapt to changing conditions based on the payloads and functions of the system it is modeled to replicate.

Beyond realistic replication, these simulations can include scenarios that challenge both human and autonomous system participants, fostering a mutual understanding of team structures, roles, and capabilities (Walliser, et al., 2019). This could be achieved through virtual and constructive platforms that provide immersive, interactive experiences. By engaging in these simulated environments, human teammates can experience firsthand how their automated teammates might perform in live situations, including potential failures, thereby improving their ability to anticipate and react to AI behaviors during actual operations.

While autonomous technologies continue to mature and emerging human-AI teams are introduced into more and more military domains, it is important to define research needs aligned to training requirements and challenges in implementation. The National Academies (2022) report on Human-AI Teaming defines six overarching research objectives associated with adult learning. At a high level these objectives aim to (1) focus training content on human-AI team mission contexts and competency requirements, (2) study traditional team-training to inform new methods, (3) train calibration of human expectation of autonomous teammates, (4) establish training platforms, (5) study adaptive training techniques based on team variations, and (6) develop training that works toward trust in human-AI teaming (National Academies, 2022).

Emerging Adaptive Learning Capabilities

Next-Generation Conversational Agents

A unique element of technologies such as ChatGPT and other large language models is their conversational interface, where learners engage in a natural back-and-forth dialogue to drive their experience. By conversing with a large language model, learners can actively construct knowledge through questioning, elaboration, and receiving tailored feedback, mimicking the collaborative discourse seen in effective human-to-human teaching and learning (Goldman, 2018). The conversational nature facilitates social negotiation of meaning and drives refining mental schema as knowledge components are directly addressed and assessed through conversational engagement (Graesser et al., 2005).

The adaptive and personalized pathways large language model conversations enable also connect to core tenets of constructivism of active learning theory (Bada & Olusegun, 2015). As learners engage in discourse on learning contexts and scenarios, large language models can tailor their responses to the learner's prior knowledge, bridging their experience to new concepts. This aligns with constructivism's view of learning as an active process of making meaning tied to existing mental models (Roschelle, 1997). For military learners, large language model-driven simulations allow safe, experiential exploration of complex situations, enabling concrete experience, reflective observation, abstract conceptualization, and active experimentation, the core cycle of experiential learning (Goldberg et al., 2021).

Large language models also have the potential to affect game-based learning environments by enabling dynamic conversations with virtual characters. One key advantage of large language models is their ability to generate contextually relevant and coherent responses, allowing for natural and engaging dialogues within game scenarios (Anand & Polyak, 2024; Cox & Ooi, 2023). This capability aligns well with the principles of situated learning theory, which emphasizes the importance of authentic contexts and social interactions in facilitating knowledge acquisition and skill development (Dawley & Dede, 2014).

By incorporating large language models into game-based environments, learners can engage in immersive conversations with non-player characters that respond adaptively to the learner's inputs and actions (e.g., Kumaran et al, 2023). These conversations can be tailored to specific learning objectives, providing opportunities for learners to practice decision-making, problem-solving, and interpersonal skills within realistic simulated situations. Furthermore, large language models can generate unique dialogue paths and character responses, enhancing the ability to replay and vary game-based learning experiences. For example, new synthetic agents have been developed to provide virtual air traffic control (ATC) call, response, and guidance within flight simulation environments, interacting with human pilot inputs—both verbal and geospatial—to simulate live-flight interaction with the ATC tower (Allsop & Keeling, 2023; Ziakkas et al., 2024).

Digital Twins

Digital engineering and digital twin technology are poised to affect next-generation training and education environments, particularly in sectors where high precision and operational readiness are paramount. Digital twins, the digital representation of characteristics of a thing, provide the ability to accurately simulate the effects, reactions, and interactions of things an infinite number of times without damaging, harming, or having to replace a real thing (Mendi et al., 2021). Designers are taking advantage of advances in computing and graphical power and improved data across more variables to create increasingly complex and accurate digital twins across a variety of fields. These provide learning opportunities across any multitude of scenarios to view, study, and understand the interactions and consequences of various choices or actions. Although creating perfectly accurate digital twins for humans remains difficult, advances are increasing the complexity and appropriate responsiveness of digital human representations (Zheng et al., 2022b).

Digital engineering involves an integrated, digital-centric approach in which systems and subsystems are designed and validated through simulated environments before they are built physically (DoDI 5000.97, U.S. DoD, 2023). Combining digital engineering with digital twin technology enables designers to go beyond simply replicating physical systems or environments and instead create fully intelligent agents (Yigitbas et al., 2021). Together, these methods provide a powerful framework for developing advanced training solutions to support military learning needs.

Digital twins enhance training through focused production of high-fidelity simulations that mirror the real world or operational environment with remarkable accuracy. These digital replicas are built and iteratively updated with data from their physical counterparts, enabling them to reflect current conditions accurately. For example, a digital twin of a jet fighter or naval ship can be used for training pilots and sailors in operation and maintenance (Kaarlela et al., 2020) and as constructive assets when simulating combat scenarios. This involves integrating digital twin data outputs from actual sensors and operational systems. This application greatly enhances the realism of the higher echelon training scenarios, preparing personnel for the complexities of live operations.

Beyond physical assets, emerging virtual human designs are leveraging digital twin methods to simulate human-like interactions, decision-making processes, and generative responses in simulation aligned to a training context (Miller & Spatz, 2022). These virtual agents are equipped with AI-driven behaviors modeled on human cognition and emotional responses (Wiederhold, 2022), making them valuable participants in complex training exercises where interpersonal dynamics and team cohesion are critical. For example, virtual humans can replicate the roles and behaviors of team leaders, peers, medics, informants, or enemy combatants, providing realistic interactions that enhance the training experience through naturalistic and relationship-building behaviors, driving learner engagement, trust, interaction, and decision making (Bickmore & Picard, 2005; Swartout et al., 2013).

Integrating virtual humans exhibiting realistic decision making and behaviors into training systems significantly enhances collective training efforts. These virtual teammates can be programmed to exhibit specific behaviors or skills needed to complete mission objectives, which helps in creating training scenarios that support both individual and team learning processes (Aris et al., 2023). This allows trainees to experience a wide range of tactical situations and adapt their strategies in real time, promoting flexibility and adaptability in high-pressure environments. Another advantage of using virtual humans as digital twins in training is the detailed feedback and data analytics they can provide. Because algorithmic functions control these agents, every action they take and every decision they make can be recorded and analyzed. This data provides invaluable insights into team dynamics, decision-making processes, and operational effectiveness.

As this technology progresses, the capability of these intelligent digital twins is expected to become more advanced, with improvements in natural language processing, emotional intelligence, and autonomous decision making. This will enable even more realistic and beneficial training interactions, where virtual teammates not only participate in training scenarios but also adapt and respond in increasingly human-like ways.

As military operations and other high-stakes environments increasingly integrate sophisticated AI tools and methods into their operational environments, it is essential for personnel to be equipped not only with foundational knowledge of how AI systems function but also with insight and understanding into their real-time reasoning and limitations (Morgan et al., 2020). This is critical for establishing proper trust in automation to optimize a human-machine team paradigm. AI literacy ensures that team members can effectively collaborate with AI, making informed decisions about when to rely on automated systems versus when human intervention is necessary (Long & Magerko, 2020). This understanding is crucial for optimizing the synergies between human cognitive skills and machine efficiency, enhancing the overall effectiveness and safety of operations. Moreover, AI literacy helps in fostering trust and reliability in technology, which is essential for seamless integration and operational success in human-machine teams. Training programs focusing on AI literacy will be vital in preparing personnel for the evolving demands of future missions, ensuring they are not only users of technology but also proficient partners in a technology-driven operational landscape.

Innovations in Measurement and Assessment

Emerging Learning Analytics Methods

Advances in computational power and wireless networks have led to improved data analytics in areas such as machine learning and deep learning, enabling learning ecosystems to incorporate skill decay models, forgetting curves, and optimal spaced retrieval, for example. It also means data from physiological and neurological sensors can be better leveraged to inform learning situations (Sharma & Giannakos, 2020). The ability to collect more data can be good, but the need to ensure quality data remains paramount.

One significant trend is the use of hybrid and ensemble modeling techniques to manage analytics across multiple data sources that provide different interaction, behavioral, and physiological variables for diagnostic purposes. These approaches combine theoretical frameworks with multiple predictive models to improve the accuracy and robustness of predictions about learner performance and outcomes (Kausar et al., 2020). For example, hybrid models might fuse data from several real-time data sources to manage assessment across multiple performance dimensions aligned to a single competency framework. Cohn and others (2024) established a multimodal learning and training framework with four primary components: (1) the learning environment that establishes context, (2) available multimodal data sources, (3) data management and real-time analytic methods across each source, and (4) form feedback through prompting, data visualizations, and open learner models (Kay et al., 2020).

These approaches can also combine data across traditional learning management systems and immersive, experiential extended reality environments to better interpret proficiency and the future potential of task performance. Educators and trainers can then assess learning in more complex, mixed-reality environments where learners interact with both digital and physical elements to support longitudinal skill acquisition and sustainment. Such models can discern patterns that single-method analytics might miss, offering a deeper understanding of how different types of engagements contribute to learning outcomes.

Moreover, the field of learning analytics is expanding to include more sophisticated measures of learner engagement and task comprehension across disparate environments that support a set of shared learning objectives. This involves tracking completion rates and quiz scores and analyzing interaction data in simulation settings to assess decision-making processes, problem-solving skills, and adaptability across interdependent competencies (i.e., knowledge, skills, abilities). Similar data types can also be used to predict learning outcomes and to infer the level of interest a learner has for a particular topic or learning objective. For example, Emerson and others (2020) found that approaches combining game play data, facial expression data, and eye gaze data into a single multimodal model out-predicted models that examined each variable independently.

When considering military training simulations, analytics can evaluate how effectively personnel apply tactical knowledge in dynamic scenarios using a variety of data sources aligned to a single task framework. For example, Vatral and others (2022b) present a military-focused hierarchical hybrid modeling approach that uses a theoretically defined team-dimensional competency framework that aligns to performance data captured across an array of learning resources and immersive environments. The model was developed to manage several multimodal data sources informing low-level markers of performance evidence under a specified context. These granular statements of performance are fused together and propagated up the hierarchy to inform higher-level constructs of competency (e.g., task comprehension, situational awareness) through Bayesian knowledge tracing methods. Under this approach, several techniques can be combined to enhance the diagnostics of a given domain model. In this project, data was captured while trainees execute a scenario targeting team readiness in a mixed reality environment, simulation data is used to monitor task performance, cameras and computer vision are used to monitor team movement and coordination, microphones and natural language processing are used to monitor team communication, and wearable sensors are used to monitor stress and affective indicators.

As simulation technologies evolve, so does the capacity to collect and analyze rich data from these environments. The integration of sensors and wearables in training scenarios, for example, provides new streams of physiological and behavioral data and enables a more comprehensive assessment of learner engagement and stress responses (Lane & D'Mello, 2019; Silvennoinen et al., 2022). Analyzing these data through sophisticated learning analytics frameworks enhances the understanding of cognitive load and emotional states (Liu et al., 2017), which are crucial for designing more effective and competency-aligned experiences. Incorporating these advanced analytics into adaptive instructional systems allows for real-time adjustments to training and educational content, aligning learning activities with the individual's characteristics and context (as described in the Adaptive Learning section above)—and doing this efficiently at scale, thanks to automation. This personalized approach helps in identifying learning gaps more efficiently and providing targeted interventions when necessary.

Advancing Natural Language Processing

Analytics involving natural language processing (NLP) have the potential to affect training and education opportunities for both individuals and teams by offering deep insights into learning and teamwork processes (Mejeh & Rehm, 2024). NLP uses language analysis techniques to decode communication patterns, responses, and engagement across several learning-oriented contexts and problem types, providing diagnostic reasoning associated with higher-level knowledge comprehension and team dimensional behaviors.

For individuals, NLP technologies are instrumental in personalizing learning experiences that target higher-order cognitive processes (Kolasani, 2023; Troussas et al., 2023). By analyzing textual inputs such as essays, open-ended responses, and interaction logs, NLP pinpoints individual strengths, weaknesses, misconceptions, and learning impasses. This information enables adaptive instructional systems to customize educational content and collaborative discourse, ensuring it aligns with each learner's unique needs and maximizes their learning potential. For example, if a learner consistently encounters difficulties with particular concepts, NLP can identify these trends and adjust the educational approach accordingly—perhaps by providing additional resources or modifying the material's complexity.

In team-based environments, NLP provides tools and methods to track team-oriented processes and collaborative interactions. By evaluating audio communications, chat logs, discussion threads, and shared documents, NLP extracts insights across team roles, teamwork dimensions, leadership dynamics, and the effectiveness of collaboration (Campion et al., 2024; Green et al., 2023). These insights are valuable in military training contexts, where effective teamwork and communication are paramount. NLP analyses can reveal if certain team members are disengaged or disproportionately dominant in discussions, guiding interventions to foster more equitable and productive team interactions. In addition, advancements in NLP now incorporate sentiment analysis and emotion recognition, offering a deeper understanding of learners' emotional states, adding critical insights into accurately evaluating competencies that require application under disruptive emotional states. For teams, this means improved management of group dynamics and conflict resolution, ensuring cohesive progress toward learning objectives.

When considering emerging technology topics, integrating large language models to drive learning analytics can potentially affect the precision and adaptability of adaptive instructional systems technologies. Large language models, which excel at processing and generating human-like text, can analyze extensive textual data across a broader spectrum of content and learner interactions. This capability allows for more nuanced understanding of individual learner domain comprehension, needs, and progress, enabling even more tailored content and learning interventions. With their ability to process and generate text rapidly, large language models can provide immediate, contextually relevant feedback to learners. This is invaluable in dynamic learning environments such as simulations or real-time collaborative projects, where immediate feedback can significantly impact learning outcomes (Meyer et al., 2024). In team-based settings, large language models can provide insights into the group dynamics by analyzing communication patterns more deeply and over larger sets of interaction data (Spain et al., 2021). This can help identify not just overt behaviors like dominance in conversations but also subtler aspects like influence, persuasion, and changing group sentiment over time.

Computer Vision

Recent advances in computer vision detection and tracking capabilities have created new unobtrusive ways to collect meaningful interaction data applied directly to learning analytics. These technologies leverage video feeds from first-person point-of-reference and stationary perspectives to monitor behavioral variables aligned to individual and collective engagements

(Vatral et al., 2022a, b), with functions supported across an array of live, mixed, and virtual learning environments.

Object detection, facial feature, and gesture tracking algorithms aligned to low-cost video sources enable robust assessments across various educational settings. For example, object detection algorithms can identify and monitor the use of specific tools or equipment during training exercises. This capability is incredibly valuable in scenarios requiring technical precision, such as military or medical training simulations where the accurate use of domain-specific tools is critical. Computer vision can assess how trainees handle these instruments at granular levels of precision, with potential to inform real-time feedback that helps correct techniques immediately (VanVoorst, et al., 2023).

In virtual and augmented reality settings, gesture and motion tracking are essential for crafting interactive and immersive educational experiences. Modern computer vision techniques, capable of capturing a broad spectrum of physical motions, play a pivotal role in analyzing detailed aspects of physical tasks. In military training, for example, the precise actions performed during combat simulations can be monitored meticulously and assessed for technique, accuracy, and safety, thereby boosting the overall effectiveness of the training (Vatral et al., 2022b).

Computer vision techniques have also enhanced facial recognition and emotion detection technologies. These algorithms can detect subtle emotional cues in facial expression such as confusion, frustration, or engagement, allowing for the instructional strategies to be adapted dynamically to better address emotional states encountered during the learning process (Canedo & Neves, 2019). This is particularly important in high-pressure settings such as military training, where understanding emotional responses can significantly influence the customization of scenarios to enhance decision-making skills under stress.

Integrating computer vision with AI and machine learning facilitates collecting vast amounts of video data and enhances the efficiency of analyzing and responding to these data. Machine learning models trained on video data from learning experiences can predict performance outcomes and pinpoint areas needing intervention, fostering a highly adaptive learning environment that dynamically responds to the individual needs of learners (Khan & Al-Habsi, 2020).

Learning Analytics in Live-Instrumented Environments

The ability to collect rich data for learning analytics in live-instrumented environments is now being used in military contexts (O'Donovan et al., 2023). In live-instrumented military training environments, wearable sensors and environmental instrumentation can collect data on soldier positioning, movement patterns, physiological states, and even tactical behavior during exercises. These data can be synthesized and analyzed using sophisticated learning analytics to enhance tactical decision making, improve physical conditioning, and evaluate the effectiveness of different training scenarios on overall learning outcomes.

Integrating these analytics into military training provides a multilayered understanding of operational readiness. Military applications use these analytics to ensure that personnel are at peak performance for their roles. Advanced tools can help military trainers identify potential areas of risk, such as fatigue and stress, by analyzing data patterns over time, thereby allowing for interventions that are proactive rather than reactive. This strategic application of analytics methodologies to military training increases the effectiveness of individual training outcomes and enhances group cohesion and tactical coordination. The ability to collect and analyze extensive data in real time supports a more adaptive, responsive military training environment, leading to improved operational performance and outcomes.

Data management in a complex training environment can create challenges associated with real-time analytics and feedback loops. Recognizing issues linked to bandwidth and limitations of network range of data capture, advancements in commercial infrastructure will assist in accelerating the development of these capabilities. Continued investment in 5G networking across military installations, maturation of communication technologies that use light to transmit data wirelessly (Alfattani, 2021), and new AI models supporting logistics and data management across large, distributed environments will directly affect how data will be used to support live military training in the near future. This will require research and development of intuitive data visualization interfaces to better inform learners and decision makers on learning needs to support an objective.

Competency-Based Learning Analytics

The U.S. Army Learning Concept for 2030–2040 strategy includes competency-based approaches to learning analytics for monitoring learning and performance progression (*TRADOC Pamphlet 525-8-2*, U.S. Department of the Army, 2024), but there are challenges preventing widescale adoption and implementation across military organizational structures. Emerging new technologies and methods may help address some of these issues. These include digitally published, standardized competency frameworks, such as the Standard Data Model for Sharable Competency Definitions (IEEE Standards Association, 2021). Technical standards create a common framework across stakeholders, enabling the development of reusable processes and workflows to building these models. They also enable automation that can allow authoritative bodies to digitally authenticate assertions, such as a vocational school's assertion of a person's applied skill (Brower & Specht-Boardman, 2022).

Competency-based approaches ought to extend modeling beyond verifiable credentials to authenticate the competencies an individual or team possess. For example, researchers are applying new probabilistic modeling techniques to competency framework structures with the intention of predicting future performance based on prior experiences and evidence-derived outcomes (López de Aberasturi Gómez et al., 2022; Robson et al., 2022). The goal of this work is to leverage multimodal assessments as evidence of performance under a defined context and analyze them over time and across experiences to make inferences on the probability of future success. These methods are also informing decision-support tools and future training recommendation engines to help individuals and teams establish training plans that target proficiency needs. While there is dedicated research in this space across the collective military Services, further research is required to address standard competency and metadata definitions for experiential-focused outcomes, mathematical modeling techniques to accurately quantify probabilistic representations of competency, and user interfaces and visualizations to effectively communicate this information to various roles supporting learning needs.

Neurophysiological Sensing, Feedback, and Enhancement

Neurophysiological sensing, feedback, and enhancement technologies leverage real-time monitoring of brain activity, heart rate variability, eye movements, and other physiological signals to gain insights into a learner's cognitive state, attention level, and emotional engagement (Wang et al., 2022). These data enable adaptive learning systems to provide personalized feedback, adjust difficulty in real time, and optimize the learning experience by accounting for cognitive and emotional states experienced during the learning process (Hasan et al., 2020). Some technologies even aim to directly enhance cognitive functions such as memory, focus, and skill acquisition through neurostimulation and neuro-pharmaceutical techniques (Brunyé et al., 2022).

Investigators have developed specific applications to enhance learning outcomes and performance through human-machine interaction and collaborative decision making. As an example of neurofeedback, the Air Force Research Laboratory explored fMRI neurofeedback to enhance working memory. In this study, participants underwent neurofeedback training targeting the dorsolateral prefrontal cortex (DLPFC), a brain area associated with working memory. This intervention led to significant improvements on an n-back task, a common working memory exercise, when compared to a control group, demonstrating the potential of fMRI neurofeedback to support cognitive performance improvements (Sherwood et al., 2016).

In the area of neurostimulation, several methodologies have been explored aiming to positively impact cognitive performance and moderate emotional response. For example, the U.S. Army Research Laboratory conducted a study that used transcranial electrical stimulation (tES) to modulate brain activity associated with decision-making and working memory (Brunye et al., 2019). Participants who received active stimulation performed better on tasks involving sustained attention and response inhibition, highlighting tES's potential for enhancing performance in operational settings. Similarly, transcranial magnetic simulation (TMS) has been used to modulate cortical excitability and has been studied for its potential to alter cognitive function (Asgarinejad et al., 2024). Repetitive TMS (rTMS) is a specific form of TMS that involves the repeated application of magnetic stimulations over an extended period. rTMS has been shown to affect brain function and modulate cortical excitability, leading to changes in the plasticity of the cerebral cortex and altered cognitive functions.

This section draws from an expert review of these technologies, tools, and methods commissioned by the committee (Babiloni & Borghini, 2024) and from a recent research task group executed within the North Atlantic Treaty Organization's Science and Technology Office (Brunye et al., 2022). While promising, these approaches raise important questions about efficacy, safety, and ethics as they receive more attention.

LEARNING SYSTEMS

For military stakeholders, learning is not a *pro forma* endeavor merely carried out as a matter of protocol. Rather, training, education, and the range of informal learning carried out in military contexts has a significant purpose, and those activities are necessarily situated within the real-world context of military goals and organizations. Consequently, the ultimate practice of adult military learning cannot be studied in a laboratory or enabled in isolation; instead, a systems approach is needed.

Systems science conceptualizes the world as systems and systems of systems. It attempts to understand these systems by examining their components and the interactions of those elements as a gestalt rather than in a piecemeal manner (Monat & Gannon, 2105; Senge, 1990). This approach is essential when dealing with complex systems such as learning in an adult military environment, because component-level interventions are almost certain to produce suboptimal or unexpected results if implemented without consideration of their greater context or the dynamic interactions found within them (Luke et al., 2024).

Applied to learning in military contexts, a systems mindset recognizes that learning does not take place as a series of isolated events. Instead, learning results from an array of heterogeneous and interacting elements that are in turn affected by the larger system. Using systems theory as a lens for military learning interventions is crucial for achieving effective, sustainable, and pragmatic outcomes, particularly at larger scales, such as at a DoD-wide enterprise level, and over time.

Two emerging paradigms support a systems approach to learning. The first, Learning Engineering, focuses on the people, processes, and mindset needed to effectively achieve particular learning outcomes in complex, real-world environments. The second, Digital Learning Ecosystems, introduces a technological approach to supporting learning enterprises holistically, while adhering to engineering best practices and supporting data-informed methods at scale.

Learning Engineering

Learning Engineering is an emerging multidisciplinary field that integrates the learning sciences with human-centered design methodologies, engineering principles (Box 6-2), data analytics, and organizational performance strategies to optimize learning experiences and outcomes (Goodell & Kolodner, 2022; Goodell et al., 2023b). In essence, it is the combination of the scholarly knowledge about learning with the practical skill of implementing reliable learning systems and the application of engineering methodology. Learning Engineering provides a framework for the people and processes needed to implement learning experiences that result in the desired outcomes—particularly, but certainly not solely, to support learning via digital systems and systems at large scales.

Core principles of Learning Engineering include:

- Being data-informed throughout all aspects of the learning lifecycle
- Incorporating human-centered design across all parts of a learning experience
- Continuously improving learning activities over time
- Leveraging appropriate technologies, from pen-and-paper to advanced AI systems, and
- Aligning learning activities to organizational goals and seeking creative ways to achieve those outcomes, considering the array of components and their interactions in the system.

Learning Engineering could be framed as a correlate to implementation science, a field that examines how to bridge the research-practice gap to put science into applied action (Madon, et al., 2007; Soicher, et al., 2020). Learning Engineering provides a methodology and professional practice to implement and scale the scientific principles hard-won through careful studies and design-based research (Kolodner, 2023). Although this may sound like instructional design, Learning Engineering differs in several ways. Learning Engineering places greater emphasis on data-driven processes, uses a wider range of data sources, and adopts an iterative, continuous improvement approach.

In addition, Learning Engineering advocates for a systems approach for both processes and technologies. This includes placing emphasis on using interdisciplinary teams to implement learning activities and advocating for the interconnected lifelong learning paradigm, often aligning to the vision of a technology-enabled lifelong learning ecosystem. This emphasizes the need to carefully design the metrics and evidence that are recorded around a learning event (Martinez-Maldonado et al., 2020), and how those metrics are reported to support longitudinal assessment and trend analyses.

Learning Engineering provides a framework for the people and processes needed to implement learning technologies. Evaluations of successful and unsuccessful digital modernization efforts point to the importance of these factors, over and above the technology itself (Oesterreich et al., 2022; Sony & Naik, 2020). In addition, research on the diffusion of innovation highlights the importance of communities of practice, particularly with complex and multidisciplinary topics (Rogers, 2003). That is, Learning Engineering helps articulate the emerging best practices, whether for new learning principles or advanced technologies, provide established communication channels, and facilitate a social system of practitioners who are implementing innovations in learning.

BOX 6-2

Engineering Best Practices and Modern Learning Technologies

The following defines four important qualities of digital systems relevant to modern learning technologies: various usability factors, extensibility, interoperability, and continuous improvement.

Usability and human-centered design: A methodology that places the user at the heart of the design process and seeks to deeply understand users' needs, behaviors, and experiences to create effective solutions catering to their unique challenges and desires. In the military context, human-centered design gained importance after the Army found that many military human errors could be traced back to poor development processes that failed to sufficiently consider human performance. Further, a U.S. GAO study found that human error caused 50 percent of all military equipment failures (Kerwin et al., 1980).

Extensibility: The ease with which features can be seamlessly added to or changed within a component without requiring significant modifications to the overall system structure, dataflow, or architecture (Abdullah et al., 2019). Extensible systems allow for future enhancements and adaptations to meet evolving requirements or to accommodate changes in technology, user needs, or in the case of military contexts, the operational environment. Systems that are not designed to be extensible often require significant overhauls when new functionalities are needed, leading to increased development time and higher overall production costs.

Interoperability: DoD defines interoperability as "the ability of systems, units, or forces to provide data, information, materiel, and services to, and accept the same from, other systems, units, or forces, and to use the data, information, materiel, and services exchanged to enable them to operate effectively together. IT interoperability includes both the technical exchange of information and the end-to-end operational effectiveness of that exchange of information as required for mission accomplishment in its operational environment." (*DoDI 8330.01*, U.S. DoD, 2022, p. 41).

Continuous improvement: The incremental and ongoing effort to enhance processes, products, and services over time—typically as a series of small changes that build towards larger long-term effects. Modern digital technologies have characteristics that uniquely facilitate continuous improvement, and because of their complexity, continuous improvement approaches are often the only viable way to develop, mature, and maintain modern digital systems. Self-optimizing systems are an emerging capability that use digital continuous improvement methods in combination with AI to automatically adapt systems in response to collected data (e.g., Brooks & Roy, 2021; Sinatra et al., 2019).

Digital Learning Ecosystem

The Digital Learning Ecosystem concept of a holistic, technology-enabled network of learning activities advances a vision that shifts away from disconnected components to an integrated system of systems comprising a broad mix of formal and informal learning—potentially even including relevant employment considerations, such as job experience (Walcutt & Schatz, 2019). This is the ultimate systems approach to technology-enabled learning, and as such it necessarily incorporates many interdependent parts across the following categories (Barr et al., 2022; García-Peñalvo et al., 2015; Gomes et al., 2020; Laanpere et al., 2014; Nguyen & Tuamsuk, 2022; Schatz & Stodd, 2023):

- Instructional facilitators such as teachers, designers, and test makers
- Other stakeholders such as learners, commanders, schools, and agencies
- Front-end technologies such as e-learning portals, simulators, and extended reality learning apps
- Back-end technology infrastructure, such as data stores and network services
- Learning contents, such as multimedia instruction and competency frameworks, and
- Administrative components, such as governance processes and quality standards.

A Digital Learning Ecosystem intentionally interconnects someone's learning experiences over time, topics, delivery platforms, and environments through a technology backbone and boundary-spanning uses of data. This idea does not attempt to create a single, hierarchical system, and it is not a new technology component to be acquired. Rather, the Digital

Learning Ecosystem concept represents a new approach to technology-enabled learning that connects independent, self-governing learning components into a decentralized network so that they can function as a system of systems. The envisioned solution attempts to capitalize on modern advances in technology-enabled learning while overcoming current limitations, incorporating engineering best practices (Box 6-2), and facilitating the flexible integration of emerging technologies as they mature.

When discussing Digital Learning Ecosystems, the scope of implementation may vary. Many proponents discuss the concept at a global scale, potentially including lifelong learning across the widest range of experiences and subjects imaginable (Goldberg & Spain, 2023; Schatz & Walcutt, 2022a; Walcutt & Schatz, 2019). Others consider it more narrowly, such as solely within the context of e-learning (e.g., Aparicio et al., 2016) or only for a bounded set of stakeholders, such as the U.S. microelectronics workforce (Rude, 2023).

Regardless of the breadth of implementation, the Digital Learning Ecosystem concept embodies some common principles (Walcutt & Schatz, 2019), including:

- Support for heterogeneous learning experiences across a decentralized network
- Technology-enabled federation of learning, development, and assessment activities
- Collection, aggregation, and analysis of data across these diverse activities
- Syntactic and semantic interoperability of data
- Use of new learning strategies that support a systems (boundary-spanning) approach
- Intent to enable data-informed personalization across various grain-sizes of experience, and
- Intent to better support informal learning, including self-directed learning.

The idea of a Digital Learning Ecosystem builds on the concept of adaptive learning, but it scales those principles to broader dimensions by collecting and acting on data at local and enterprise-wide levels as a form of mass customization. At each grain-size of learning, a Digital Learning Ecosystem could implement a feedback loop, using data-informed adaptability and analyses to optimize outcomes from local levels, such as a single homework question to higher ones, such as a career progression journey (Barr et al., 2022; Hernandez et al., 2022). Ultimately, the idea is to consistently and responsively deliver the right learning experiences for each person or team, in the right forms, at the right times, as drawn from a large set of options.

Digital Learning Ecosystems may provide several benefits (Betts et al., 2020; Gallagher et al., 2018; Goodwin et al., 2017; Redmond & Macfadyen, 2020; Walcutt & Schatz, 2019). For example, proponents expect that some of the positive outcomes of contemporary adaptive instructional systems, such as learning effectiveness, efficiency, and motivation, will be expanded as adaptivity is scaled more broadly. In addition, by more intentionally interconnecting learning experiences, a Digital Learning Ecosystem infrastructure can enable technology-enabled learning component developers and human learning facilitators to create more cohesion across learners' journeys. This might mean, for example, that a particular AI-enabled intelligent tutor is able to reference and explicitly build upon a learner's prior knowledge gained from a wholly different system, on a different subject, and delivered by a different institution.

The connectivity and intelligent adaptation enabled by a Digital Learning Ecosystem is also anticipated to better support self-directed learning, because when learning content is exposed digitally to the larger system, technologies can help individuals navigate that landscape. This may mean, for example, that search tools incorporate context-sensitive factors and use recommendation methods such as collaborative and content-based filtering to help learners more successfully forage for their learning experiences. As an example, a military maintenance person who needs on-demand just-in-time support may be aided by algorithms that automatically identify the context, the equipment being serviced, the maintainer's current skill level, and the available delivery technologies, and then use that information to recommend the best materials for that situation.

In addition to anticipated learning-science benefits, proponents of the Digital Learning Ecosystem concept also highlight engineering advantages (Dagger et al., 2007; Redmond & Macfadyen, 2020; Sinatra et al., 2019). Necessarily built for technological interoperability and extensibility, a Digital Learning Ecosystem is expected to support more efficient and responsive technology-enabled learning implementations. This means a Digital Learning Ecosystem is better able to integrate new technologies as they are developed and to support continuous improvement processes.

By connecting various components and, importantly, enabling their syntactic and semantic interoperability, the Digital Learning Ecosystem creates new opportunities for AI optimization. In that regard, the digital infrastructure underlying a Digital Learning Ecosystem creates a data pipeline that can fuel machine learning algorithms that support individuals, institutions, and large-scale agencies. For example, at personal levels, the aggregation of data could be used to inform a lifelong digital twin. At programmatic levels, such as for a schoolhouse, data collected from many people over time could help surface patterns of success among learners, such as which behaviors are most likely to produce optimal academic outcomes. At broad organizational levels, the aggregation of data could inform forecasting algorithms, such as personnel readiness predictions.

Consequently, such data-informed, AI-enabled learning management is not only expected to support better learning experiences; it is also theorized to enhance military outcomes (e.g., Schatz & Walcutt, 2022b). With these optimization objectives defined, their dependency on sensitive data cannot be ignored. Establishing business rules and data management policies to protect identifiable and traceable information through ethical secure practices is critical (Hampton & DeFalco, 2022). While an ecosystem's maturation depends on the storage and aggregation of large amounts of context-rich learning data, there are opportunities to sanitize and potentially encrypt data at multiple levels to ensure that sensitive information is accessible only to those with proper authority. An infrastructure of this nature needs to be designed to account for a full implementation paradigm, with considerations on protections for personnel anonymity and security against cyber intrusions and threats.

The technology required to implement a Digital Learning Ecosystem can be complex, starting with a data infrastructure that includes data standards and centralized systems and policies for facilitating data collection, aggregation, storage, transmission, and interoperability. A Digital Learning Ecosystem needs to include user-facing technologies with which learners, learning facilitators, and instructional designers interact. It also requires back-end technologies, such as cloud-based microservices that help authenticate users' identities and store individuals' aggregated data across applications. This implementation approach, with its focus on a technological backbone with front-end and back-end technologies, follows a model similar to how the internet functions. That has led some practitioners to colloquially refer to the Digital Learning Ecosystem concept as the "internet of learning things" (Gordon et al., 2020).

The predominant technical component of a Digital Learning Ecosystem is its data infrastructure, the technological backbone that enables syntactic and semantic interoperability. Different categories of data are relevant, but often with emphasis on the following components:

- Run-time data, such as a learner's performance within a particular activity
- Learner-worker profiles, including longitudinal aggregate data and personal details
- Content metadata, describing the learning experiences within the system
- Competency frameworks, to create a common definition of topics and performance levels
- Distributed identity, to authentic users' identity across systems, and
- Verifiable credentials, to authenticate achievement tokens across systems.

The next most notable component of a Digital Learning Ecosystem is the content found within it. Content includes, but is not limited to, a variety of media with which learners interact. Different categories of content within the system include the following:

- Learning materials, such as multimedia instruction and simulation scenarios
- Associated learning science components, such as pedagogical models
- Tests and assessments, such as examinations and performance standards, and
- Instrumentation, such as embedded data hooks and learning analytics.

These components can be built incrementally and initially at local levels, and practitioners have begun to offer maturity models with recommend pathways for gradual achievement (Malone et al., 2020; Reardon et al., 2020; Schatz & Stodd, 2023). Similarly, existing technology-enabled learning systems can be updated gradually to include the necessary components, such as data standards and user interfaces to join the ecosystem. That is, the Digital Learning Ecosystem approach offers a way to modernize existing technology investments while creating a framework for incorporating new technologies as they become viable. Achieving this vision will address a demand signal that DoD has recognized for over two decades (Carter, 2016; Gates, 2008; Mattis, 2017, p. 7; U.S. Joint Chiefs of Staff, 2015). It also aligns with contemporary U.S. military strategies, including the *Army Learning Concept for 2030-2040* (*TRADOC Pamphlet 525-8-2*, U.S. Department of the Army, 2024), the Air Force's *Sixth-Generation Learning Environment* concept (Davis, 2023), *Naval Education Strategy* 2023 (U.S. Department of the Navy, 2023), *Marine Corps Doctrinal Publication #7: Learning* (U.S. Marine Corps, 2020), and the U.S. Coast Guard's *Ready Workforce 2030* (U.S. Coast Guard, 2022).

CURRENT LIMITS OF PRACTICE

Despite the promise of many new technology-enabled learning solutions, practical issues make integrating them into military organizations a challenge. DoD security requirements to protect its IT infrastructure and service member information often require multiple access levels or restrictions, which prevent or slow down new technology acquisition and integration (e.g., common access card login requirements). The DoD acquisition process is also long and arduous, with limited ability to quickly adjust to emerging innovations or service needs. However, even within these constraints, many challenges stem from investments made without using a systems approach, such as making acquisitions in a piecemeal manner and focusing on immediate, local outcomes to the detriment of longer-term, organizational outcomes. In other words, the DoD is challenged, not so much by the invention of new technologies, but rather in successfully implementing them in real-world systems at appropriate scales.

This problem has been widely acknowledged and well-studied, and the root causes of it within the U.S. military have been documented (Defense Innovation Board, 2024). For example, the exciting pace of technological advancement convinces some leaders that buying the newest technologies will overcome shortfalls in mission achievement—albeit with minimal analysis of the root causes of those shortfalls and little effort put towards identifying a fit-for-purpose solution. As a result, new capabilities are sometimes forced into old systems without a clear strategy for success, with limited sustainment resources, and without corresponding updates to the legacy systems in which they are embedded. Ultimately, such acquisition methods often result in rising costs with comparatively no improvements to learning outcomes (e.g., Puentedura, 2006).

Challenges with implementation are particularly acute for digital technologies, which are sensitive to systems-level interaction effects and require organizational planning. As such, even when a particular problem and solution are carefully planned at the local level, they may still create problems across the organization or over time.

For example, with few exceptions the U.S. military has invested in standalone experiences and use cases for its technology-enabled learning innovations. These detached technology-enabled learning components may provide viable methods for maximizing learning in narrowly defined instances, but the proliferation of disparate learning technologies creates organizational challenges. The acquisition of countless redundant technologies—and often proprietary and incongruent—creates a fragmented landscape. For example, hundreds of internal DoD organizations have invested in similar technologies, but those systems operate independently. The lack of interoperability in DoD systems drives up costs, limits opportunities to use data-informed approaches, and makes it difficult to incorporate new capabilities effectively (e.g., Smith et al. 2018).

Solutions to these challenges include acquisition system reform and changes to DoD's digital innovation processes. As DoD's digital modernization strategy recognizes, "delivering IT capabilities with greater efficiency and performance requires the Department to reform the way it operates" (p. 24) to include shifting from a component-centric approach to an enterprise-wide model and optimizing the way DoD handles data (*DoD Digital Modernization Strategy*, U.S. DoD, 2019). More recently, the Defense Business Board remarked on the same issues, including the need for an integrated digital ecosystem, lack of an interoperable data strategy, and a workforce that is not adequately prepared for a digital ecosystem approach (Defense Business Board, 2024).

While individual investments in technology-enabled learning systems and the study of technology-enabled learning-component best practices are valuable, the U.S. military is likely to see marginal returns from investments focused on standalone technologies. To reap the highest return on investment, the DoD can from the beginning pair them with systems approaches, including Learning Engineering and a Digital Learning Ecosystem approach.

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7
Learning Assessments and Evaluation

Across many pathways, military learners engage in continuous learning throughout their careers, raising important questions about assessing and evaluating learning experiences. Assessment and evaluation of adult learning can serve a variety of purposes, with purpose being a critical issue in determining which assessment approaches are most useful, as different approaches are effective for different purposes. In that regard, this chapter describes which approaches to assessing and evaluating adult learning and developmental outcomes are most effective, and which deficiencies in the current approaches might impede accurate measurement of learning and developmental outcomes. The chapter begins by defining terms and then identifying various purposes of assessment and evaluation of adult learning. After discussing various assessment and evaluation frameworks, the chapter considers important attributes of tests and assessments and reviews approaches to evaluation, focusing on the validity of inferences drawn from evaluation studies.

DEFINITIONS OF TESTS, ASSESSMENTS, AND EVALUATION

The committee uses a number of definitions set out in the *Standards for Educational and Psychological Testing (The Standards)* (AERA et al., 2014), a widely recognized document providing "a basis for evaluating the quality of [testing] practices" (p. 1). These definitions include the following:

- **Assessments**: "Any systematic method of obtaining information, used to draw inferences about characteristics of people, objects, or programs; a systematic process to measure or evaluate the characteristics or performance of individuals, programs, or other entities, for purposes of drawing inferences; sometimes used synonymously with *test*" (p. 216).

- **Tests**: "An evaluative device or procedure in which a systematic sample of test taker's behavior in a specified domain is obtained and scored using a standardized process" (p. 224).
- **Program evaluation**: "The set of procedures used to make judgments about a program's design, its implementation, and its outcomes" (p. 203); policy studies and accountability are broader, but related concepts. Program evaluation uses the data collected during the assessment process.
- **Validity**: "The degree to which evidence and theory support interpretations of test scores for proposed uses of tests" (and note that "it is the interpretations of test scores for proposed uses that are evaluated, not the test itself") (p. 11).

The committee notes that the Educational Testing Service's (ETS) (2014) *Standards for Quality and Fairness* defines the terms "test" and "assessment" as synonymous[17] and defines test as "a systematic sample of behavior taken to allow inferences about an individual's knowledge, skill, ability, or other attribute" (p. 62). Assessment and evaluation of adult learning can serve a variety of purposes. Purpose, therefore, is a critical issue in determining which assessment approaches are most effective, as different approaches are effective for different purposes.

High- and Low-Stakes Assessment

One important dimension of test use concerns the stakes associated with a test's scores. High-stakes tests are those "used to provide results that have important, direct consequences for individuals, programs, or institutions involved in the testing" (AERA et al., 2014, p. 219). One high-stakes assessment that many enlisted personnel encounter early in their career is the Armed Services Vocational Aptitude Battery (ASVAB). This assessment is high-stakes because it directly informs their classification into their military occupational specialty. Other examples include promotion tests, recognition and award tests, and end-of-course summative pass/fail assessment. For these situations, test scores have important, direct consequences for the individual test taker.

Low-stakes tests are those "used to provide results that have only minor or indirect consequences for individual[s], programs, or institutions involved in the testing" (AERA et al.,

[17] The committee has chosen to use the terms *test* and *assessment* interchangeably because, in general, they adhere to the same standards, but also acknowledges that assessment is the broader term.

2014, p. 221). These include classroom assessments or quizzes, assessments for learning, or formative assessments; tests used in program evaluation or to determine unit readiness; and tests used for research purposes, including longitudinal studies to monitor change, where there are no direct consequences to the individual based on test performance.

Formative vs. Summative Assessment

Another key distinction in the purpose of an assessment is between formative and summative assessments. Formative assessment is "an assessment process used by teachers and students during instruction that provides feedback to adjust ongoing teaching and learning with the goal of improving students' achievement of intended instruction outcomes" (AERA et al., 2014, p. 219). Summative assessment is "the assessment of a test taker's knowledge and skills typically carried out at the completion of a program of learning, such as at the end of an instructional unit" (AERA et al., 2014, p. 224).

Navy flight training incorporates both formative and summative assessment. Specifically, this form of training consists of numerous graded simulator and live flight events. Military learners are graded across specified maneuvers and their learning, and progress toward proficiency is monitored. This represents formative assessment. At certain points in the training, learners go through "checkrides," which are summative assessments, similar to a final exam in an academic setting; these flights evaluate whether the student has reached the necessary proficiency across multiple maneuvers within specific skillsets (e.g., navigation and instrument flying). Failure during individual simulator or flight events does not drastically affect training if the learner later demonstrates proficiency. However, failure during a "checkride" initiates a review of the student's training which can result in remediation or attrition from the program (*CNATRAINST 1542.166D,* Chief of Naval Air Training, 2024).

Evidence-Centered Design

Evidence-centered design is an approach to assessment design that ensures when building the assessment that the assessment process includes collecting validity evidence (Almond et al., 2015; Arieli-Attali et al., 2019; Mislevy, 2007; Mislevy & Yan, 2017; Mislevy et al., 2003). The evidence-centered design framework starts from the claims one wishes to make about a test taker or group of test takers and then works backward by considering the strength of evidence needed to support those claims and approaches for eliciting evidence relevant to the claims. It also provides specifications for analyzing and modeling domains and for implementing and delivering an assessment. In addition to supporting the design of assessments generally—from traditional to novel and innovative assessments—evidence-centered design can support the development of intelligent tutoring systems that include assessments as part of their design, including when those systems are based on simulation and game-based assessments (Mislevy & Yan, 2017).

CONSTRUCTS—COMPETENCIES, KNOWLEDGE, AND ATTITUDES TO BE LEARNED AND THE STATE OF ASSESSMENT

Constructs are the attributes assessed to reflect either learning that has occurred or the readiness to learn further, and as this report has demonstrated, the list of potential constructs to assess in the military context is vast. The Army's Talent Attribute Framework, introduced in Chapter 2, exemplifies the wide range of knowledge, skills, and attributes that military members may need in the Army. Traditionally, constructs have been characterized as either hard skills, such as cognitive and technical competencies, or soft skills, such as, teamwork, communication, and curiosity. In the upcoming section, both hard skills and soft skills are discussed.

Hard Skills

For the purposes of this report, hard skills include most of the competencies listed in the cognitive, expertise, and personal competence domains in the Army's Talent Attribute Framework, along with general cognitive, spatial, verbal, and language competencies measured in the ASVAB, the Defense Language Aptitude Battery, and similar batteries for the purposes of personnel selection and classification. Additional tests used for specific military occupational specialties can include assessments of technological, medical, technical, and mechanical competencies. Hard skills are often measured with multiple-choice tests, although short-answer tests are used widely outside the military.

The taxonomy of educational objectives, known colloquially as Bloom's Taxonomy, provides another useful framework for assessing hard competencies such as psychomotor competencies, physical strength, and stamina. Historically, assessment has been concerned primarily with measuring hard skills, such as reading, writing, arithmetic, and coding, and this is where the field's understanding of assessment is most mature. Therefore, assessment procedures for these competencies are well established and tests are readily available depending on the specific requirements (e.g., Gershon et al., 2013; LaForte et al., 2024; U.S. Office of Personnel Management, n.d.). However, there has been an increased focus over the past two decades on measuring, the "softer" 21st century skills, though the assessment practices for these are less mature and ripe for further research (Geisinger, 2016; National Research Council, 2011), which we discuss next.

Soft or Durable Skills

So-called soft or durable skills encompass a wide range of attributes that have traditionally been thought to be hard-to-measure or less tangible than hard, or technical-type, competencies, but at the same time are thought to be critical precursors and outcomes of learning. In the larger employment market, certain soft competencies are regarded as particularly important in that they often appear in surveys of employers under the heading of what employers are looking for in new recruits.

For example, a National Association of Colleges and Employers survey found that the highest rated career readiness competencies as rated by employers were communication, teamwork, critical thinking, professionalism, equity and inclusion, which were all rated between very and extremely important (National Association of Colleges and Employers, 2023). Technology, career and self-development, and leadership were rated between somewhat and very important (National Association of Colleges and Employers, 2023). For some competencies, particularly communication, teamwork, critical thinking and professionalism, the survey found a considerable gap between importance and proficiency, that is, importance was high, but the judged proficiency of recent graduates was lower. Recently, studies have employed various methodologies other than employer surveys to identify those competencies likely to be increasingly valued in the workforce. These methodologies include analyses of labor market trends (Autor et al., 2022; Deming, 2017) and analyses of predictive artificial intelligence (AI) (Frey & Osborne, 2017) and generative AI capabilities (Eloundou et al., 2023) to perform job tasks (Kyllonen et al., 2024).

As this report has discussed so far, military learners are frequently encouraged and are generally motivated to learn many soft skills. The learning objectives of Professional Military

Education, introduced in Chapter 2, articulate this point. For military learners to advance to more senior ranks they are required to learn many soft skills, including leadership, communication, and ethical decision making (see Table 7-1 for a crosswalk of a desired learning outcome; additional information is in Appendix C). Recently, the U.S. Army Research Institute for the Behavioral and Social Sciences conducted a study to identify the most important attributes for noncommissioned officers, warrant officers, and officer assignments (Royston & Amey, 2023; Royston & Lin, 2022; 2023). For each attribute incumbents were asked, “How important is the knowledge, skill, or behavior to the performance of your current assignment?” The attributes receiving the highest importance ratings from noncommissioned officer incumbents included communication ability, sound judgment, mental agility, stress tolerance, and dependability. (Royston & Amey, 2023, p. iv).

One recent idea is that some of the hard skills may have a short life span because of changing work requirements, changes in technology, or even changing operational contexts. This provides additional impetus to focus assessment attention on these soft skills, which are thought to be more transferable or durable across situations and across changes in technology; the durable competencies label has gained cachet in discussions of competencies of the future workplace (National Research Council, 2012). These considerations are also reflected in recent discussions about the military-to-civilian transition period (Chapter 5). Many military learners are aware of the need to pursue a second career after service and may be motivated to learn competencies that are transferable and relevant within the civilian sector. Despite the increasing importance of such soft skills in the military, additional research is needed to improve assessments.

TABLE 7-1 Example of Desired Outcomes of Senior Professional Military Education, Including Joint Learning Areas and Desired Leader Attributes

Joint Learning Area (JLA)	**Desired Leader Attributes (DLA) and Professional Military Education Outcomes**
<u>JLA #2: The Profession of Arms</u> • Are first and foremost members of the profession of arms, sworn to support and defend the Constitution, with specialized knowledge in the art and science of war.	• **<u>DLA #3</u>**: Operate on intent through trust, empowerment, and understanding (the essentials of Mission Command)

• Demonstrate joint-mindedness and possess a common understanding of the values of their chosen profession demonstrated through sound moral judgement and the embodiment and enforcement of professional ethics, norms and laws. • Apply the principles of life-long learning and demonstrate effective joint leadership and followership.	• **DLA #5**: Make ethical decisions based on the shared values of the profession of arms

SOURCE: Committee generated, text verbatim from *CSJCI 1800.01F*, U.S. Joint Chiefs of Staff (2020).

Team- and Group-Level Competencies

As Chapter 3 noted, teams are essential in the military. Examples of assessable team-level competencies include organizational cohesiveness and unit readiness. Recent research has reviewed approaches to measuring team cohesion, identifying task, social, belongingness, group pride, and morale dimensions that could be assessed with both attitude and behavior measures (Salas et al. 2015). Salas and colleagues (2015) found that social and task measures of cohesion had the strongest relationships with performance. They also pointed out limitations in failure to account for dynamic changes longitudinally. They found that most measures were survey methods, but that innovative and unobtrusive measures, such as big data, sociometric badges, physiological measures, content analyses, and external observer measures were also used, suggesting a productive future research avenue (Salas et al., 2015).

Some tests, such as the National Assessment of Educational Progress, are designed to produce assessments that reflect group-level scores (Beaton & Barone, 2017), which means that scores are reported to enable comparing groups rather than individuals. These assessments use planned missing-data designs that involve administering a subset of the test item pool, reducing respondent burden in the administration of these tests (Little & Rhemtulla, 2013).

Contexts and Types of Training

There are several contexts of adult learning (Chapter 3) to consider for determining the appropriateness of assessments and evaluations. In formal training and education contexts, standardized tests are typically administered and accompanied by a more formal evaluation design. Training in an informal context—e.g., informal field-based learning—is not often accompanied by formal assessments or formal evaluation designs. Similarly, self-regulated or self-directed learning involves the self-teaching and self-study to create durable competencies useful for on-the-job performance and career advancement, which often does not involve formal evaluation. Another context in the military is the after-action review, which is almost never subject to assessments or evaluation designs.

There are also variations in the kinds of military training that can be administered. Technical and operational training pertain to the instruction and learning of the technical and operational competencies needed for the job. Institutional Professional Military Education includes the training that individuals receive at institutions such as the Army War College and the Army's Command and General Staff College; the College of Naval Command and Staff; the College of Naval Warfare; Air University; and Marine Corps University. These are accredited programs, but as the U.S. GAO pointed out (*GAO-20-323*, U.S. GAO, 2020), additional information is needed to assess their effectiveness.

METHODS OF ASSESSMENT

There are many approaches to assess constructs, but for the purposes of this report the committee chose to divide them into three categories—self- and other-report methods; administrative records and data-mining approaches; and performance methods. These three methods are associated with different competencies: performance methods with hard competencies, self- and other-report methods with soft or durable competencies, and administrative records with both. The measurement and psychometric issues differ for the three categories.

Self- and Other-Report Methods

Self- and other-report methods are traditionally used as the method of choice for measuring 21st century skills (National Research Council, 2012). They are most often rating scales, such as Likert scales, and they are subject to well-known biases, including:

- Response-style effects—a tendency to respond in a certain way regardless of item content, such as favoring the extremes of a scale or responding in the middle
- Reference group effects—a tendency to represent oneself relative to a reference group rather than on an absolute scale

- Social desirability bias—a tendency to endorse items that represent socially desirable attributes, and
- Halo and horn effects—a tendency to generalize a positive or negative rating across all items rather than rating each item objectively.

These biases can result in non-differentiating response patterns across dimensions of interest, meaning they are not more or less likely depending on the construct being studied. Coinciding with the increased attention on soft skills, there have been significant developments in self- and other-report methods in recent years. Several meta-analyses, for example, have shown that others' ratings are superior to self-ratings in many respects (Connelly & Ones, 2010; Oh et al.2011) since they avoid social desirability bias (but are more subject to halo and horn effects) and have been shown to be better at predicting outcomes compared to self-assessments (Connelly & Ones, 2010).

Research has shown that forced-choice methods—requiring people to choose between two options that differentiate based on traits—outperform rating-scale methods in reliability and in predicting outcomes (Cao & Drasgow, 2019; Salgado & Táuriz, 2014). Item response theory methods, which require a large number of subjects, produce item characteristic curves for each item that reflect the characteristics of people likely to endorse those items (Stark et al., 2005). They are ideal for scoring forced-choice items (Brown & Maydeu-Olivares, 2011; Stark et al, 2005) but are more challenging in the test assembly phase. However, methods have been developed to automate development using these approaches (Kreitchmann et al., 2022).

Administrative Records and Data-Mining Approaches

Administrative records include all categories of records, including social media records, which are kept routinely on students, employees, and military members. These often serve as the basis of a learning assessment for program evaluation, personnel assignments, and the determination of readiness. Increasingly, researchers are using data-mining methods to find patterns in such records and draw inferences in a manner similar to how inferences are drawn from item responses in testing. For example, procrastination has been inferred from registration records (Richardson et al., 2012, as cited in Kyllonen & Kell, 2018), and personality traits have been inferred from information gathered from Facebook pages (Kyllonen & Kell, 2018). The extent to which social media data specifically have been used in military contexts is unclear.

However, continuous advances in technology and data collection efforts will likely support these approaches being used in the military.

Performance Methods

Performance methods include approaches for drawing inferences about the level of an attribute possessed by a participant in a performance task, including standardized tests. This is the most mature methodology for assessment, and the literature on human capabilities relies almost entirely on performance on standardized tests. Much of psychometrics—the psychology discipline devoted to testing, measurement, assessment, and related activities—is based on analyses of performance on standardized tests. Simulations are performance tasks that extend the capabilities of standardized tests and expand the ways individuals can be assessed. There is considerable research on using simulations for assessment (e.g., Ryall et al., 2016; see also Chapter 6).

One exciting development is the attempt to develop performance measures for soft 21st century skills, such as communication, collaboration, and creativity. This includes stealth tests—methods of continually tracking a person's progress while providing immediate, automated responses—to measure creativity (Shute et al., 2016) and gamification techniques (Landers & Sanchez, 2022; Kyllonen et al. 2024; Kyllonen & Zu, 2024; Kyllonen, 2023). Additional research in the military is needed to understand best practices on integrating technology to advance stealth assessments (see Chapter 8).

VALIDITY, RELIABILITY, AND FAIRNESS OF ASSESSMENTS AND EVALUATIONS

The foundations of testing are the psychometric qualities of tests, which are their validity, reliability, and fairness. Issues of the validity, reliability, and fairness of evaluations can also be addressed independently of the validity, reliability, and fairness of the assessments used in those evaluations. Although the concepts are similar, the terminology is different and the concepts come from the experimental design (Shadish et al., 2002) and causal inference literatures (Morgan & Winship, 2015), not from the testing, assessment, and psychometrics literature. The following section focuses on test validity.

Test Validity

Although there are different perspectives on the validity of assessment scores (Lissitz, 2009), two have been particularly influential. One is the *validity argument*, which sees the validation process as one of obtaining evidence from multiple sources to draw inferences supporting the use of a test for a particular purpose for a particular population (Kane, 1990; Mislevy, 2007). This has come to be the mainstream view within psychometrics, as reflected in *The Standards* (AERA et al., 2014). A challenge for this view is that this concept of validity does not conform to the relatively simple idea, and the belief commonly held by researchers, that validity concerns whether a test measures what it purports to measure (Borsboom et al., 2004). Thus, in response to the *validity argument* view, an alternative conceptualization is referred to as *ontological realism* (Borsboom, 2005). This is the idea that a test is a valid measure of a construct to the degree that when the level of the construct changes, the test score changes along with it, just as when the temperature changes the thermometer reading does, too. A challenge for this alternative view is that psychological constructs are often fuzzy or poorly understood, unlike the case with many physical constructs such as temperature.

There has been a concern within psychology with deficiencies in constructs (De Boeck, et. al., 2023), which has resulted in either downplaying the role of constructs or pleas for better measurement. An example of the former is the focus on modeling specific responses to replace constructs (Borsboom, 2017; Borsboom et al., 2021). Examples of the latter are suggestions for upscaling operational definitions of constructs and better matching constructs and measures (Flake & Fried, 2020). There has also been a proposal to reformulate constructs, recognizing their explanatory function and emphasizing their heterogeneity and variability in content and measurement and their hierarchical nature from general to specific. Validity generalization (Schmidt & Hunter, 1977) is an important concept in testing applications to justify the use of tests in a particular setting. It is based on the idea that the use of high-stakes testing not only is supported by local validity studies but can also be justified by combining similar studies through a meta-analysis.[18]

[18] Biddle and Nooren (2006) discuss the legal status of validity generalization arguments.

General Assessment Validity Threats

Scholars have suggested (e.g., McCallin, 2006) that there are two overarching threats to assessment validity: construct-irrelevant variance, and construct underrepresentation. *The Standards* (AREA, 2014) defines these two concepts as follows: Construct-irrelevant variance is "variance in test-taker scores that is attributable to extraneous factors that distort the meaning of scores and thereby decrease the validity of the proposed interpretation" (p. 217). Construct underrepresentation is "the extent to which a test fails to capture important aspects of the construct domain that the test is intended to measure, resulting in test scores that do not fully represent that construct" (p. 217).

Examples of construct-irrelevant variance would be a test of mathematics proficiency that used complex English language which caused trainees, particularly non-native English speakers, to perform worse than they might otherwise perform had simpler language been used (Abedi, 2006). Situational judgment tests, such as using unfamiliar scenarios to assess collaboration, might be another example of construct-irrelevant variance (Haladyna & Downing, 2004). An example of construct underrepresentation would be an assessment of one of the so-called Big 5 personality traits,[19] such as conscientiousness, that failed to include items measuring one of its facets, such as rule-following. Another example would be a general reasoning test that failed to include inductive reasoning (Downing, 2002; Spurgeon, 2017).

In addition to these two validity threats, several potential validity threats have been associated with various assessments, particularly innovative computerized item formats (Sireci & Zenisky, 2015). These include anxiety and lack of engagement for those not familiar with the technology used by the assessment; stereotype threat; the extent to which a test's time limit alters a test taker's performance as a result of a lack of familiarity with the technology; and security issues. Related to time, there are several timed assessments in the military. While the ASVAB is a timed test, the speed at which it is completed is not factored into scores. On the other hand, the Navy's Aviation Selection Test Battery, for example, is used as part of the criteria for selection into flight school for Navy, Marine Corps, as well as the Coast Guard. There are specific subsections of this test battery in which timing is used in the calculation of scores and is directly tied to performance.

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[19] Extraversion, agreeableness, openness, conscientiousness, and neuroticism.

Validity Threats for High-Stakes Testing

When an assessment is used for high-stakes purposes, such as for personnel selection and classification, receipt of a special, desirable assignment, or (from the standpoint of a leader) unit success, then cheating is a likely validity threat. If the stakes apply to the individual, then the cheating concern would focus on the individual; if the high stakes applied to a program or class, the cheating concern would focus on the individual responsible for that program or class. Grade inflation (Ahn et al., 2019) is an example of a practice that is a response to the use of grades for high-stakes purposes. For assessments involving ratings, lack of inter-rater reliability is also a source of validity threats. This specific concern involves both high- and low-stakes assessment. Boyer (2020) reviews methods to address these.

Finally, anxiety, such as test anxiety or math anxiety, is another validity threat to high-stakes testing, as test takers might be impeded from displaying their true ability because of test-related anxiety. A meta-analysis concluded that test anxiety's effects can be in the small to moderate range, which can be significant in decision making (von der Embse et al., 2018). A meta-analysis with university students compiled evidence for intervention efficacy on test anxiety and academic performance, showing the strongest evidence for behavior therapy, although new interventions are becoming available (Huntley et al., 2019).

Validity Threats for Low-Stakes Assessments

With assessments used for low-stakes purposes, such as formative assessments or group assessments to determine unit readiness, cheating and coaching are not typically problems. Instead, the biggest problem is likely to be test-taker effort and motivation (Weirich et al., 2016; Wise & DeMars, 2005), which depresses scores overall and for some test takers more than others. In rating studies, which can be seen as low-stakes to the rater, prominent validity threats include non-differentiating response patterns across dimensions of interest. Anchoring effects may also bias performance ratings, such that exposure to a high anchor is likely to lead to higher performance appraisal ratings (Belle et al., 2017).

Reliability/Precision of Test Scores

Reliability "is the extent to which [test scores] are consistent across different occasions of testing, different editions of the test, or different raters scoring the test taker's responses"

(Livingston, 2018, p. i). *The Standards* (AERA et al., 2014, p. 33) points out that reliability is used two ways: in classical test theory as a reliability coefficient, which is the correlation across two equivalent forms of a test, and more generally as the consistency of scores across replications of testing. This latter use includes many diverse approaches to determine consistency, such as the standard error of measurement (Wainer & Thissen, 2001), generalizability coefficients (Brennan, 2001), classification consistency (Sinharay & Johnson, 2019), and item-response theory information (de Ayala, 2009).

In classical test theory, observed scores are considered to be a sum of true scores plus error scores. Generalizability theory (Brennan, 2001; Cronbach et al., 1972) extends this concept of reliability to consider various sources of error variance in test scores, such as time, raters, test forms, and replications. Thus, reliability can be apportioned to these sources, and designs can be developed to change or fix sources to maximize the generalizability of measurement (Shavelson et al., 1989). Item response theory introduces the important idea that reliability varies depending on the score, so that it is possible to have reliable measurements at some areas of the score scale, such as in the middle, and less reliable measurements in other areas, such as the extremes (Haertel, 2006; Yen et al., 2006).

Reliability is a limiting factor for validity in the sense that low reliability makes it difficult to establish evidence for the validity of a measure. Ways to overcome reliability limitations can include longer tests, more observations, or the administration of additional items. Reliability generalization is a method similar in spirit to validity generalization and is potentially useful for meta-analyses, in which the mean and variance of reliability estimates of measures is summarized along with sources of variability (Sánchez-Meca, et. al., 2021; Vacha-Haase, 1998).

Fairness: Disparate Effect, Measurement Invariance, and Beyond

Fairness is a complex and often fraught topic. Within testing and psychometrics, it is considered “a fundamental validity issue” (AERA et al., 2014, p.49). The basic concern as it pertains to fairness is avoiding measurement bias. *The Standards* additionally includes accessibility, meaning “an unobstructed opportunity to demonstrate [all test takers’] standing on the construct(s) being measured” (p. 49) and universal design (p. 50), which addresses accessibility issues through all stages of test design. The Educational Testing Service’s fairness guidelines define fairness as “the extent to which inferences and actions based on test scores are valid for diverse groups of test takers" (ETS, 2022, p. 74), and reviews construct-irrelevant barriers to success including knowledge, skill, and ability barriers such as specialized knowledge, translation, religion, unfamiliar item types, and U.S. culture, and emotional barriers such as avoiding certain sensitive topics, stereotypes, and violence.

There are two common topics relating to fairness on the data analysis side, and in a sense two broad definitions of fairness. One of these relates to adverse or disparate impact. This is a guideline defined under Title VII of the Civil Rights Act of 1964 and in the Uniform Guidelines on Employee Selection Procedures (U.S. General Accounting Office, 1978), which states that in a selection or employment screening context, the selection ratio of a protected group needs to be at least four-fifths of the selection ratio of the non-protected group to avoid the presumption of adverse impact. By this definition, a test, or screening procedure is considered fair if it does not disproportionately reduce the chances of a protected group member being selected.

Another topic relates to measurement invariance. Measurement invariance is a statistical procedure used to determine whether the items in a scale measure the same attribute for all groups taking the test and therefore can be interpreted the same way regardless of the group (Millsap, 2011), a concept that pertains to differential prediction or prediction invariance as well (Millsap, 2011, Chapter 9). By this definition of fairness, a test is fair to the extent that the test measures the same construct(s) for different groups of test takers, and that different groups of test takers with equal ability levels will have the same probability of answering an item correctly (or endorsing an item) and the same expected test score. Measurement invariance testing is becoming more commonplace, but some (e.g., Sterner et al., 2023) argue it is still underutilized. Van de Vijver and colleagues (2018) discuss methods for addressing measurement invariance issues.

Although these are the key concepts in fairness as represented in *The Standards* (AERA et al., 2014) and comparable documents, the topic of fairness is the subject of significant research attention and may evolve as a result. Recent discussions of fairness include equity considerations, which consider opportunity to learn and other factors, such as social and cultural factors, that might operate on groups or individuals. Some of these factors, such as opportunity to learn (Elliott & Bartlett, 2016) or socio-cultural factors (Sinharay & Johnson, 2024), are difficult to quantify, as noted in *The Standards*. A revised version of *The Standards* may accommodate and clarify some of these issues (Herman et al., 2023).

BOX 7-1

Fairness and Fitness

To illustrate the concept of fairness in the military context, consider the Army Fitness Test. The Army introduced this test in 2017, and it includes several physical fitness behaviors such as a standing power throw and a two-mile run. It was designed to (1) assess if Soldiers are ready to perform combat tasks, (2) prevent injuries, and (3) promote a culture of fitness in the Army. The RAND Corporation conducted an independent review of this test, and found the evidence base supports some, but not all, components of the test (Hardison et al., 2022). Upper body power, as measured by the standing power throw, was only slightly predictive of injury risk, whereas running was strongly related. Men and women showed larger differences in performance on the standing power throw than on the running task. The discrepancy between the physical fitness construct, which includes injury prevention in its conception and justification, and the lack of strong predictive power in the throwing event demonstrates how the throwing event could be considered construct-irrelevant to the fitness construct for the Army's purposes and, thereby, not a fair and valid measure of fitness for these purposes (Hardison et al., 2022).

SOURCE: US Army, n.d. Army Combat Fitness Test. Retrieved May 2024 from https://www.army.mil/acft/

Modeling Change and Competencies Growth Longitudinally

There is a large literature on modeling longitudinal data (Gibbons et al., 2010; Hedeker, 2004) relevant to the assessment and evaluation of adult learning and developmental outcomes. These sources review issues associated with modeling change generally. For the modeling of specific competencies invoked during instruction, the literature on adaptive instructional systems, or intelligent tutoring systems (see Chapter 6) is informative. These systems typically include a student model, which represents the student's current level of knowledge regarding the curricular elements, or knowledge components being taught.

Bayesian knowledge tracing (Corbett & Anderson, 1994) models the learning of knowledge components (competencies) over time, as shown by performance on exercises, as a function of initial skill mastery, learning the skill after item completion, forgetting the skill, and making slips (answering incorrectly despite having mastered the skill), and guesses (answering correctly despite not having mastered the skill). Shen and colleagues (2024; see also reviews by Abdelrahman et al., 2024; Liu, 2022) review the considerable research base on different knowledge tracing approaches, which they classify into (a) Bayesian models (a kind of Hidden Markov Model [HMM]) (e.g., Bulut et al., 2023), (b) logistic models (learning factors analysis, performance factor analysis) (e.g., Pavlik et al., 2009; Schmucker et al., 2022), or (c) deep learning models (deep knowledge tracing, memory-aware knowledge tracing, attentive knowledge tracing, graph-based knowledge tracing) (e.g., Piech et al., 2015), along with hybrid models (Zanellati et al., 2024). The review finds that deep learning models tend to outperform Bayesian and logistic models, but at the expense of interpretability. Variants on traditional knowledge tracing approaches accommodate learner differences in learning rate or knowledge, learner engagement, forgetting, and side information (student or performance information other than responses, such as response times, whether the tutor intervenes, item text content, and student language proficiency) (Shen et al., 2024).

Although student modeling and knowledge tracing would appear to share common ground with psychometrics, there is remarkably little that links the two disciplines (although Jacobucci & Grimm, 2023, provide a general treatment). Work by Wilson and colleagues (2016) showed that an item response theory (IRT) model outperformed a deep learning model in predicting student item performance. One publication (Deonovic et al., 2018) compares IRT and Bayesian knowledge tracing models, proposing a unified framework, but also pointing out the limitations of each, which are that neither can account for inputs from teaching and education. In a recent publication, Bulut and team (2023) discuss similarities and differences between Bayesian knowledge tracing and IRT and cognitive diagnostic modeling and provide an open-source Python package to estimate Bayesian knowledge tracing models. A major difference between Bayesian knowledge tracing and IRT (and cognitive diagnostic modeling) is that IRT and cognitive diagnostic models assume ability level is fixed, whereas Bayesian knowledge tracing (and other knowledge tracing methods) models the change in ability over time. However, others (Bolsinova et al. 2022a; 2022b; Deonovic et al., 2020) demonstrate a novel approach to determine the probability of an individual learner's success on an exercise in conditions where ability changes, based on the Urnings algorithm. This novel approach is similar to the Elo (1978) rating system and the preference models of Bradley and Terry (1952) and Luce (1959), where ability is compared with item difficulty in the same way that two chess players are compared with each other in Elo ratings. Dynamic factor analysis has also been proposed as an approach to ability updating over time in psychology (Ram et al., 2013; Zhang & Browne, 2010) and in economics (Cunha et al., 2010).

VALIDITY IN EVALUATION

Validity in evaluation pertains to the validity of inferences about the effects of a treatment on outcomes or associations of a treatment with outcomes. For example, an inference that a particular intervention led to an increase in learning outcomes might be more or less valid, depending on the whether the evaluation design included a proper control group and whether the treatment was implemented properly. As with test scores, for which validity is not a property of the test, with evaluations validity is not a property of the method or design of the evaluation, but of the inferences drawn about the relationships between treatment and outcomes (Shadish et al., 2002).

Kirkpatrick Evaluation Framework

Kirkpatrick's four levels framework for program or intervention evaluation (Kirkpatrick & Kirkpatrick, 2006) is a prominent evaluation approach, widely used in industry for evaluating training likely due to its simplicity and value, and by now its ubiquitousness in practice. The framework evaluates training at four levels: reaction, learning, behavior, and results. The reaction level addresses affective responses to the training, such as whether trainees liked the training and if the instructor considered the training relevant and useful. The reaction level is typically measured with post-training surveys. The learning level addresses whether trainees learned the content (knowledge, competencies) from the training. This level is also typically assessed with post-training questionnaires or tests, but also with interviews or observations.

Evaluations at the behavior and results levels are more difficult to assess than reaction and learning level evaluations and are consequently less likely to be conducted, but they are nevertheless critical. The behavior level refers to whether the training transferred to on-the-job behavior, and whether behavior changed following training. Behavior-level evaluation is typically conducted with observations, interviews, peer and supervisor ratings, and other performance metrics where available. Behavior-level evaluation also is commonly assessed longitudinally, immediately after training and after an interval (e.g., 6 months), to study persistence in any affected training behaviors. This level of evaluation is typically more challenging than reaction and learning-level evaluations, because of the complexity of on-the-job behavior and the requirement for the involvement of performance observers.

Results evaluations pertain to effects of the training on business measures, such as organizational performance metrics, or other indicators businesses use (e.g., complaints, customer satisfaction, employee retention statistics, financial indicators, lawsuits) that might be affected by the training. Some of these metrics may be part of management information routinely collected or could be based on special surveys. Return-on-investment calculations can be conducted to quantify the costs and benefits of the training on metrics that matter to the organization. Results are significantly more difficult to calculate than for the other levels because the metrics are affected by many factors other than training effects, such as employee movement through and out of the organization, broader organizational changes, and larger external factors that might affect the business or the organization unrelated to the training content.

The Kirkpatrick model is widely used in training evaluation, including its levels serving as moderators for meta-analyses of training effects (Arthur et al., 2003). One recent publication (Nawaz et al., 2022) reports that most studies evaluate reaction and learning, with far fewer evaluating behavior and results. Over the years, there have been proposals for improving on the Kirkpatrick framework in various ways. One notable alternative is a taxonomy of cognitive, skill-based, and affective learning/training outcomes accompanied by associated evaluation measures (Kraiger et al., 1993). This modified framework has been proven widely useful in research, but it has not replaced Kirkpatrick's framework as an organizational standard.

Evaluation Standards

Several bodies have created evaluation standards; here we review two. These standards go beyond the issues covered in Kirkpatrick's framework to address many aspects of conducting an evaluation or program evaluation.

The Joint Committee on Standards for Educational Evaluation includes the American Evaluation Association, Canadian Evaluation Society, American Psychological Association, National Council on Measurement in Education, U.S. Centers for Disease Control, and several other coalition members.[20] The third edition of *The Program Evaluation Standards* is available

[20] https://evaluationstandards.org/about/sponsoring-organizations/

in book form, with examples from practice (Yarbrough et al., 2010) along with a checklist (Joint Committee on Standards for Educational Evaluation, 2018). The standards cover the topics of utility (e.g., credibility of evaluators, timely reporting), feasibility (e.g., procedures, project management), proprietary (e.g., fairness, transparency, conflicts of interest), accuracy (e.g., reliability, validity, justifiability of conclusions), and accountability (e.g., documentation, meta-evaluation) and are designed for education and non-education evaluations of programs and policies.

The U.S. Office of Management and Budget (March 10, 2020) produced a memo (M-20-12) providing guidance for federal agencies to meet requirements of the Foundations for Evidence-Based Policymaking Act of 2018. The memo describes "high-level consensus standards and practices currently recognized for their value in supporting a variety of Federal evaluation needs" (p. 1). It includes the standards of relevance and utility (e.g., producing findings that are actionable and available in time for use); rigor (e.g., as related to design, implementation, interpretation, limits), independence and objectivity (e.g., of the evaluator, avoiding conflicts of interest), transparency (e.g., study documentation, release of results), and ethics (e.g., equitable and fair evaluations, abidance by professional standards in treatment of participants). The memo provides definitions of key terms, outlines evaluation practices, and provides an extensive bibliography of evaluation standards and practices at federal agencies and other interested bodies.

Together, these two sets of standards are usually considered essential best practices for conducting evaluations of adult learning and developmental outcomes. However, the evaluation standards are abstract, particularly when it comes to design issues and the quality of evidence ("accuracy" in the Joint Committee on Standards for Educational Evaluations standards; "rigor" in the Office of Management and Budget memo). We thus explore this issue in more depth.

Quality of Evidence Issues

Drawing from multiple sources (Campbell & Stanley 1963; Shadish et al., 2002), the U.S. Department of Education Institute of Education Sciences (IES) has developed evidence standards useful for evaluating the strength of evidence supporting claims of treatment efficacy (IES, 2022). These standards are central to the mission of the What Works Clearinghouse, which is "to be a central and trusted source of scientific evidence for what works in education" (IES, 2022, p.

6). The What Works Clearinghouse, established in 2002, reviews, studies, and synthesizes results across studies. It provides three products: reviews of individual studies; intervention reports, which are syntheses of evidence from multiple studies that reviewed an intervention; and practice guides, which are syntheses of evidence on teaching methods, learning strategies, and approaches to learning that may improve learning outcomes. For each of these products, What Works Clearinghouse first determines whether the study or studies are eligible based on the study design and other factors, and if the study is eligible, What Works Clearinghouse provides a determination about the strength of the evidence provided in the study (IES, 2022).

To be eligible, What Works Clearinghouse considers several factors, including study design, time frame, sample, outcome measure, and location (IES, 2022). For the purposes of this report, the key issue is what research designs are eligible. Those eligible are randomized control trials, quasi-experimental designs, regression discontinuity designs, and single-case designs (IES, 2022). Quasi-experimental designs include cross-sectional group designs, comparative interrupted time series, difference-in-difference designs, and growth-curve designs. Notably excluded are single-group pretest-post-test designs. After evaluation, What Works Clearinghouse provides a research rating pertaining to whether the research meets these standards. For studies meeting What Works Clearinghouse standards, What Works Clearinghouse publishes effectiveness ratings based on effect sizes and statistical significance, also considering sample sizes, whether the intervention occurred in multiple settings, and the absence of overriding negative effects (IES, 2022). These factors together are considered in arriving at effectiveness ratings, which apply not only to meta-analyses but to individual studies as well.

Cook and Campbell Framework on Validity Threats in Evaluation

There are a wide range of threats to the validity of inferences about the effects of treatments on participants (internal validity) and on generalization to the target population (external validity) (Cook & Campbell, 1979; Shadish et. al., 2002).

Internal Validity

Threats to internal validity are reasons for a relationship between a treatment and an outcome other than a causal relationship. Possible alternative explanations or threats to the validity of an inference that A caused B (e.g., a treatment [e.g., training, a new policy] caused behavior [e.g., increase in good behavior, decrease in bad behavior]) include the following (Cook & Campbell, 1979; Shadish et al., 2002):

- *Temporal precedent*: If the behavior change came first, then the relationship could be that the behavior caused the policy; e.g., training did not increase sexual harassment, but instead, a rash of sexual harassment charges led to mandatory training.
- *Selection*: The treated group differed from the non-treated group prior to treatment, making it appear that the treatment had an effect when it did not; e.g., only the most highly motivated military learners volunteered to receive special training, leading to an erroneous conclusion that the training increased learner motivation.
- *History*: Concurrent events; e.g., a physical training exercise program is implemented, but around the same time the team moves from a one-story to a two-story building, leading to more daily stair climbing, which makes it difficult to infer that unit strength and stamina gains came from the exercise program alone.
- *Maturation*: For example, a year-long training program appears to result in decreased problem behaviors, but non-treated individuals also would have shown a decrease due to being more mature a year later.
- *Regression*: Extreme scores will regress to the mean; e.g., military learners with the worst scores on a test on the gun range are given special training, which appears to increase their scores dramatically, but even without the training there would have been an expected increase in their scores due to regression to the mean; or the best performers are given a retest and found to score lower the second time, falsely leading to the conclusion that their performance decline was due to overconfidence or "resting on their laurels."
- *Attrition*: Loss of respondents to treatment; e.g., huge gains in unit performance from the beginning to the end of training are found not to be due to the effectiveness of the training as much as to low performers dropping out.
- *Testing*: Exposure to the test can affect subsequent test scores; e.g., instructors "teach to the test," focusing more time and attention on concepts that they know will be on the final test.
- *Instrumentation*: The measure or conditions of measurement may change over time; e.g., instructors are pleased that their average course grade this year was 10% higher

than last year's, but then realize that the test changed and the gains might simply have been due to an easier end-of-course exam.

- Finally, there are additive and interactive effects of more than one threat.

Threats to the related concept of statistical conclusion validity include the following (Shadish et al., 2002):

- *Low statistical power*: For example, an experimental training only involved a handful of students, making it impossible to determine if it was effective compared to an untreated group.
- *Violated assumptions*: For example, the statistical model assumes a normal distribution of scores, but scores were mostly 0% or 100%, invalidating the test statistic.
- *Fishing and the error rate problem*: Failing to correct for the number of tests being conducted; e.g., to determine if the training affected student outcomes, hundreds of student measures were analyzed, and a few showed a significant change, but by chance a few would have shown a significant change.
- *Unreliability of measures*: For example, a conclusion of "no effect of training" was reached, when it is found that the measures given to students to evaluate the training were unreliable.
- *Restriction of range*: For example, a conclusion that there is only a small correlation between ASVAB and performance in electronics training when high ASVAB scores were a condition for entry into electronics training artifactually reducing that correlation.
- *Unreliability of treatment implementation*: For example, the training might have worked but the instruction materials did not arrive on time and the instructors changed several times mid-course.
- *Extraneous variance in the experimental setting*: For example, training was interrupted by a fire drill.
- *Heterogeneity of units*: For example, the training was designed for enlisted personnel, but officers were included in the same class because the officer training was not ready.

External Validity and Generalizability in Inferences About Treatment Effects

External validity concerns the generalization of a causal relationship, that is, whether it holds over variations of persons, treatments, and outcomes both within and outside the study (Shadish et al., 2002). Threats to external validity include whether the relationship would hold with other kinds of units, such as a different group of students; interaction over treatment variations, that is, whether the effect would hold if the treatment varied somewhat from the way it was given; interaction with outcomes, that is, whether the effect might disappear with a different outcome measure; and interaction with settings, that is, whether the treatment would work in a different locale or at a different time.

External validity is sometimes limited as a result of failing to identify a target population when designing a trial or recruiting a sample from that population and when considering a population different from the one targeted by the trial (Stuart et al., 2015). Some researchers have proposed statistical weighting methods to estimate effects on populations that might vary somewhat from the population targeted in the study (Tipton & Olsen, 2022). Additionally, Tipton and Olsen (2018; 2022) provide guidelines on assessing the generalizability of randomized trial results to target populations for educational interventions. One method of generalizing from a sample to a population uses multilevel regression and post-stratification, a survey adjustment technique (Kennedy & Gelman, 2021). This method works when there is at least some representation from the various subgroups of the target population.

Generalizing to populations can be faulty in the presence of significant moderator variables pertaining to subgroups. A treatment may be effective for males but not females, for example, in the same way that a measure may test different constructs for males and females. Thus, one way to think about fairness in evaluations analogous to fairness in assessments is through the absence of moderator effects pertaining to individuals or subgroups. A finding of an efficacious treatment effect can mask interactions with subgroups, for whom the treatment is not effective. This determination requires that an appropriate analysis is conducted to detect such possible moderator effects (Wang & Ware, 2013).

Construct Validity

Construct validity is related to generalizability, but it pertains to generalizing from the specific instruments used in a study to the broader, underlying constructs the instruments were intended to measure. One publication (Shadish et al., 2002) lists 14 threats to construct validity, or why inferences about constructs in a study may be incorrect. These include:

- *Inadequate explication of constructs*, such as an unclear definition of "reasoning ability";
- *Construct confounding,* when more than one construct is affected by a treatment;
- *Mono-method bias,* when all construct operationalizations use the same method, such as self-reports as measures of personal attributes;
- *Confounding constructs with levels of constructs,* as when only some levels of a construct are studied, such as a low level, but an inference is made to all levels of the construct, low to high; and
- *Experimenter expectancies*, such as when an experimenter expects the treatment to work and so tends to focus on observations supporting treatment efficacy.

Core Components

The core components of an intervention or training program refer to the elements of the program or the "active ingredients" that are critical for producing positive outcomes from the program (Blase & Fixsen, 2013). Finding that a particular program or intervention is successful in producing positive adult learning outcomes compared to a control group, for example, does not by itself identify which aspect of the program was responsible for the success of the program. On the one hand, it could be that the program increased trainees' engagement and motivation, or was more likely to be implemented correctly, or on the other hand it could be that a particular instructional technique produced greater learning. Determination of core components is important in refining and scaling up a program (Lawson et. al., 2019; Van Melle et al., 2019).

Value-added Modeling

Value-added modeling is the use of measures of pre- and post-intervention change on standardized tests taken by students to draw inferences about the effects of individual instructors. Although these methods are useful for policy purposes in that they can evaluate the effects of covariates on instructor practice, such as whether experienced instructors improve student achievement more than less experienced instructors do, they are problematic for individual judgments because of low reliability (Newton et al., 2010). The method has also been criticized for showing effects on short-term rather than long-term outcomes and encouraging teaching to the test (Carrell & West, 2010), even when that is less effective on average (Phipps, 2022).

Causal Identification from Observational Studies

In evaluating programs, training, and policies, one often would like to know what the potential outcomes would be under different treatments. For example, would military learners learn more or learn faster if taught in the classroom with a lecturer or in pairs with an intelligent tutoring course (Sottilare et al., 2018). Although they have their limitations, randomized control trials—for example, in which military learners are randomly assigned to either a classroom or intelligent tutoring training and their performance on a final achievement test is compared—are widely seen as ideal for drawing causal conclusions and estimating causal effects from data (Deaton & Cartwright, 2018).

However, there are many circumstances in and outside of the adult learning context where there is interest in making causal inferences, for example about the effects of a policy or training on outcomes, but where randomized control trials are not possible. Instead, the researcher, policy maker, or practitioner can only rely on data from observational studies involving no manipulations. For example, researchers have used data from observational studies to draw causal inferences, such as that smoking causes cancer (Cornfield et al., 2009), educational attainment increases health and social outcomes (Davies et al., 2023), and schooling boosts IQ (Brinch & Galloway, 2012), even without experiments.

Studies have relied on regression analysis to draw causal inferences, using control variables, but this approach is limited because of the possibility of biased causal estimates resulting from confounding or failing to include important variables in the model. For example, the number of books in the home predicts students' academic achievement, but both might be the result of parental influences, such that there may not be a causal connection between books in the home and achievement. Similarly, engaging in regular exercise might predict promotions, but both might result from a third variable, such as conscientiousness. The validity of causal inferences from observational studies depends on including and properly adjusting for all variables that might affect a given correlation.

To provide a better basis for causal inferences, investigators have developed a variety of quasi-experimental techniques to approximate an experiment in observational studies. These include matching, instrumental variables, difference-in-difference, and regression discontinuity designs (Angrist & Pischke, 2009; Gelman et al., 2021; Rosenbaum, 2017; Schneider et al., 2007).

Matching is designed to replicate a randomized experiment by approximating random assignment into treatment and control in cases where treatment and control cannot be randomly assigned. It does this in two parts: in the design part, the researcher identifies cases in the treated and the control datasets that match on other covariates, such as demographic, academic, and nonacademic factors. The matching is accomplished without considering the outcome variable (Stuart & Rubin, 2007). Following this, the two matched groups, treatment and control, are compared on the outcome to estimate the treatment effect. There are many matching methods (King & Nielsen, 2019; Morgan & Winship, 2015; Stuart & Rubin, 2007). King and Nielsen (2019) point out limitations of one particularly popular approach—propensity scores—for matching.

The instrumental variable method is an approach to estimate a causal relationship, using a variable—an instrument—that is correlated with the treatment assignment, but only affects the outcome via that treatment assignment, and it is not correlated with other variables not included in the model that might correlate with the outcome. The instrument thus plays a role similar to random assignment. Instrumental variables can be identified through "natural experiments." One example comes from a study in Norway from the 1960s which enabled the examination of the effects of schooling on IQ (Brinch & Galloway, 2012). Norway implemented a new schooling system requiring a change in compulsory schooling over a 17-year period affecting 14- to 16-year olds, but affecting different municipalities in different years. This in effect was a natural experiment that manipulated mandatory schooling, with the instrument being the new schooling system, implemented at different times. Assuming that increasing the length of education was the only means by which the outcomes (IQ scores and educational attainment) were affected (e.g., not by quality of education based on the reform), the study found that an additional year of schooling increased education by 0.16 years and IQ by 3.7 points.

Brinch and Galloway (2012) subjected the same Norwegian dataset to a difference-in-difference analysis, another approach for estimating causal effects. Here the authors compared "the change in IQ scores from the pre-reform period to post-reform period for municipalities that introduced the reform in a given year with the change in IQ scores in that same period in municipalities that did not introduce the reform in that particular year" (p. 426).

The regression discontinuity approach involves situations where treatment participation is not assigned randomly, but might instead depend on a treatment-determining variable (Imbens & Lemieux, 2008), such as summer school for those failing to meet standards on a year-end achievement test (Matsudaira, 2008) or having exam scores high enough to qualify for entry into elite exam schools with academically attractive peers (Abdulkadiroğlu et al., 2014). The effect of the treatment can be seen in cases close to the selection variable cutoff. A meta-analysis has shown that regression discontinuity designs can yield treatment effect estimates similar to ones from randomized control trials (Chaplin et al., 2018).

Frameworks and Formal Models of Causal Identification

The potential outcome model of causal inference (Neyman, 1923/1990; Rubin, 2005) is the basis for much of the research on causality in economics, statistics, and, increasingly, social and health sciences (Morgan & Winship, 2015). The core idea is that individuals can be exposed to two alternative "states of a cause" which are referred to as alternative treatments or a treatment and control. Causal effects can be understood as "a comparison between different potential outcomes of what might have occurred under different scenarios" (Gelman et al., 2021, p. 339) or alternative treatments. The potential outcomes approach addresses causal inference in a systematic and formal way, which includes notation, terminology, and concepts to describe the process of drawing causal inferences. The potential outcomes framework is concerned with estimating causal effects, such as the average treatment effect (ATE) for individuals, and aims to address issues such as the effect cognitive ability has on earnings (Cunha & Heckman, 2007) or the other causal effects discussed in the immediately preceding section.

A related framework, the directed acyclic graphs framework (Pearl, 2009; Pearl & Mackenzie, 2018), is a causal modeling approach that expresses relations between variables in a graphical path diagram, often called a causal diagram. The framework categorizes causation into three levels—association, intervention, and counterfactuals—to represent the increasingly sophisticated types of causal queries it can address. A directed acyclic graph comprises nodes (representing a set of variables) and directed edges (arrows) that represent the causal direction between variables. Nodes can be connected by chains (e.g., XàMàY), forks (e.g., XßMàY), or inverted forks (e.g., XàMßY). Colliders, or common effects, are nodes with at least two directed arrows pointing to them, that is, a variable appearing in the middle of an inverted fork. Back door paths are indirect connections between a treatment, X, and outcome, Y, that are not represented in the path of the arrows.

There are various treatments in the literature that address the compatibilities and distinctions between the two frameworks (Heckman & Pinto, 2023; Imbens, 2020; Morgan & Winship, 205). Heckman and Pinto (2023) distinguish the econometric causal model and point out the benefits of relying additionally on theory to bolster causal arguments.

Aided by a directed acyclic graph analysis, Elwert and Winship (2014) suggest three underlying challenges to identifying a causal effect from data: overcontrol, confounding, and endogenous selection bias. These concepts are further described in Table 7-2.

TABLE 7-2 Challenges to Identifying Causal Effects

Challenge	Defined
1. **Overcontrol Bias**	Refers to the situation in which the researcher conditions on a variable lying on the causal path between two variables, such as conditioning on treatment implementation in determining the relationship between treatment and outcome. That is, a variable, M, in the X-Y causal path is controlled for (X-M-Y), resulting in an incorrect inference of no relationship between two variables (X, Y) that are causally connected.
2. **Confounding or Omitted Variable Bias**	Refers to the situation in which a causal variable is not included in the model, such as when determining the effects of training on outcomes without including ability and personality as covariates. That is, a common cause (Z) is not controlled for (or conditioned on) resulting in an incorrect inference of a relationship between X and Y.
3. **Endogenous Selection Bias or Selection Bias (or Selection Effect)**	A condition in which participants are not representative of the intended population due to sampling methods, recruiting, or inappropriate identification of a population. Examples in adult learning would be drawing inferences about the efficacy of an instruction program based on a post-program survey that had a low return rate. That is, the analyst conditions on a collider variable, where the collider is caused by the treatment (or a variable associated with the treatment) and the outcome (or a variable associated with the outcome). For example, in determining the effects of schooling (S) on wages (W), test scores (Q) may be a collider because they are affected by both unmeasured ability (U) and schooling (S) and so conditioning on test scores induces endogenous selection bias.

SOURCE: Committee generated.

ADDITIONAL ISSUES

Cost Considerations

A cost analysis is useful for considering the viability of various forms of assessment and evaluation. Guidelines for conducting cost-effectiveness analyses for education interventions have been developed (Levin & McEwan; 2001; Levin & Belfield 2015). In addition, IES provides a starter kit to estimate the costs of interventions; although developed for education, the principles are applicable to training generally (IES, 2020). The key considerations include first determining the relevant level for the assessment or evaluation, such as the individual, team, unit, organization, or institution level, depending on the unit on which the assessment or evaluation might be conducted. The next issue is determining the cost method. A cost-benefit analysis can be conducted when outcomes can be expressed in monetary units, but when they cannot, then a cost-effectiveness or cost-utility analysis can be done.

Following this, a cost data collection and calculation can be planned. There are various approaches, but an ingredients (or resource cost) method to estimate total costs of the program is common. The analyst identifies the ingredients necessary for the intervention incremental to the training resources currently available in the unit, enabling a marginal cost analysis. Ingredients may include personnel, facilities (e.g., additional space), software, equipment (e.g., computers if not otherwise available), trainer training, program hosting and web services, and overhead. A cost valuation then uses price, depreciation, and client inputs, as well as a cost worksheet, to identify costs and allocate them among constituencies, which could include various potential stakeholders. The valuation would include inflation adjustments and discounting over time.

The IES (2020) starter kit provides a systematic way to go about documenting costs, including personnel, time, training, and materials costs associated with treatment implementation. A benefit of conducting cost analyses is that they can guide future adopters who might be considering implementing a program at similar institutions, units, or organizations. Another benefit is realizing the value of a particular kind of training. For example, Belfield and others (2015) estimated that investing in social-emotional learning programs in education yielded positive returns: Every $1 invested in effective programs provided a return of approximately $12 to U.S. society. Similar analyses can be conducted for adult learning generally, or in the military context.

Score Reporting Using Performance Standards

It is common in the military context to report performance on tests and assessments administered during training on a 0 to 100 scale, where the scale value indicates either the number or a percentage of items correctly answered, often with 70 or 80 as a passing score. Although such scaling and reporting has the benefit of transparency and user familiarity, it is worthwhile to consider alternatives, such as performance standard setting. Standard setting is "the proper following of a prescribed, rational system of rules or procedures resulting in the assignment of a number to differentiate two or more states or degrees of performance" (Cizek, 1993, p. 100). In education, performance on standardized tests is often reported in categories, such as basic, proficient, and advanced. In credentialling, performance is often characterized as pass/fail or award/no award based on one or more cut scores from an examination. Research has generated a large body of literature that seeks to provide a scientific foundation for setting performance standards to support decisions about promotion, selection, placement, and credentialling, with an acknowledgement of its social, economic, educational, and political importance (Cizek, 2012).

There is a distinction between performance standards—the conceptual version of the desired level of competence—and passing scores, which are the operational version (Cizek, 2012; Kane, 1994, p. 426). This is a useful distinction because it serves as the foundation for standard setting in that it allows an organization or group to decide on the desired level of competence and determine the passing scores necessary to achieve that. Methods of standard setting are designed to identify what a desired level of competence means and to determine a corresponding passing score.

A wide variety of methods are used for standard setting (Zieky, 2012). One popular and prominent approach is the Angoff method, which involves deciding on a passing score on a test by having each participant, such as a judge or committee member, estimate the probability that a minimally acceptable person would answer each item correctly and then averaging the probabilities over the items in the test and the participants. Modified Angoff methods involve providing normative data on item responses to the participants and allowing iterations. The

Angoff method involves many judgments, so another popular method, the bookmark method, reduces the number of judgments that the participants need to make by sorting items from easy to difficult based on prior data collection. Then, participants place a bookmark on the most difficult item borderline test takers would likely answer correctly and the easiest item borderline test takers would likely answer incorrectly.

Other approaches for setting standards include:

- The *benchmark method*, which involves statistically linking test scores to another test, setting performance-level descriptions;
- The *body-of-work method*, which involves considering bodies of work beyond a particular test and setting performance-level descriptions (Kingston & Tieman, 2012);
- The *item-descriptor-matching method*, which involves considering the content, competencies, and processes each item requires (Ferrara & Lewis, 2012);
- The *briefing book method*, which begins with potential cut scores and derives performance standards for them (Haertel et al., 2012); and
- *Model-based approaches*, involving the use of statistical classification models (Templin & Jiao, 2012).

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8
Conclusions, Recommendations, and Research Agenda

In this final chapter, the committee presents its conclusions, recommendations, and research agenda. Given that the areas of literature discussed in the report are deeply interconnected, the committee developed conclusions that are based on the accumulation of evidence presented across all the preceding chapters. Conclusions and recommendations are organized based on several key themes.

AUTONOMY AND LEARNING DEVELOPMENT ACROSS THE LIFESPAN

Conclusion 1: Service-specific core values define the military environment, serve as stable guiding principles, and set strong expectations. Cultural components, that are generally more global, such as hierarchy, collectivism, and respect can influence how learners behave and how they navigate their learning pathways.

Conclusion 2: Although the U.S. Navy and Air Force have increased their use of vocational interest tools, there is typically no guarantee in any of the Services that a given military member will be assigned to a military occupational specialty aligned with their interests.

Conclusion 3: Adult learners will be more motivated to learn and seek out learning experiences when learning is aligned with and leads to personally valued outcomes.

Conclusion 4: Several key characteristics of military policies, practices, and cultural values create power distance that may limit how much individual autonomy a given military learner can have in practice. These include, for instance practices regarding occupational specialty placement and up-or-out promotion policies. These contextual factors can impede learning by limiting individual-level learner autonomy.

Conclusion 5: People retain the capacity for growth and change throughout their life. Relative to later in life, young adulthood is a period of high levels of fluid ability and an emerging sense of purpose, fragmented knowledge, and heightened needs for exploration and establishing the self. Accumulated knowledge, developed competencies, and commitment to goals are strengths of midlife in their own right that can also largely compensate for the subtle decline in fluid abilities that may appear in midlife. These changes affect the ability to learn and motivation for learning.

Conclusion 6: The considerable variability in competencies, knowledge, and experience among adults, combined with the strong time constraints related to multiple adult roles, justifies personalizing instructional design to optimize learning.

Conclusion 7: Learning styles that define universally applicable categories are not the same as personalized instruction. Learning styles are not supported empirically, and using them in formal learning contexts can negatively affect learning outcomes.

Conclusion 8: In general, motivation and goals change through adulthood to prioritize emotional regulation and social connectedness over exploration and acquisition of information, trends that emerge in midlife. This has implications for goals, values, and preferences for activities and social engagement as it relates to learning. For the most part, maturity in adulthood brings opportunities for greater alignment of behavior with purpose and goals.

Recommendation 1: To the extent feasible and appropriate, Department of Defense organizations should allow military members to exercise disciplined autonomy over their career pathways and individual learning trajectories:

- **Leaders of all Service branches should continue encouraging and rewarding military members for being proactive in attending to their own self-development by, for example, seeking informal learning opportunities and mentorship. In addition, the Department of Defense should formalize policies where needed to provide resources such as time, in accordance with mission constraints, to allow for these activities.**

- **To advance military readiness, the U.S. military should continue training leaders to foster a culture that encourages and promotes proactive self-development. This may include strategies on effectively communicating learning data to individual learners.**
- **Training Commands and Professional Military Education institutions should continue to identify opportunities for military members to exercise individual autonomy in learning, for example seeking elective courses and mentorship. Opportunities may vary based on factors such as military occupational specialty.**
- **The Army Office of the Deputy Chief of Staff for Personnel should implement validated vocational interest tools to gauge military recruits' interests and leverage recruits' sense of autonomy by better aligning occupational placement to vocational interests, in accordance with mission constraints. For example, the Army could implement the Adaptive Vocational Interest Diagnostic assessment that has been evaluated in Army samples, or develop new vocational interest assessments that more closely parallel those adopted by the Navy and Air Force.**

ALIGNING LEARNING WITH JOB ROLES

Conclusion 9: The pathways for enlisted and officer personnel define the primary formal learning trajectories in the military context. The specific competencies military leaders aim to instill in their members along these pathways tend to vary based on the level of a member's experiences, occupation, and specific assigned jobs. Learning objectives typically progress over time from tactical and technical to increasingly strategic, with leadership skills enforced throughout.

Conclusion 10: Although Department of Defense civilians account for a significant percentage of the military, their learning pathways are inconsistent and not as formally structured compared to enlisted and officer learning pathways.

Recommendation 2: The Defense Human Resources Activity, in coordination with the Service personnel offices, should augment opportunities, incentives, and enterprise-wide governance methods for supporting Department of Defense civilian learning and development. This work should better organize and make discoverable these opportunities and align them to mission needs and to professional development opportunities.

Conclusion 11: The operational landscape of the military has expanded rapidly across multiple domains and is defined by increasing degrees of volatility, uncertainty, complexity, and ambiguity, all while remaining dangerous. This systemic shift creates new demands to maintain a military trained and educated on a greater variety of competencies, such as 21st century skills, that are applicable across a broad range of needs and circumstances and require practice in diverse contexts for their flexible use.

Conclusion 12: As learning objectives typically progress from tactical to strategic, many competencies—such as 21st century skills—beneficial for complex operational environments are taught in later stages of the pathways, as military members work toward promotion.

Conclusion 13: The Department of Defense explicitly defines military learning to include the development of "attitudes" and aims to instill military core values such as integrity, respect, and selfless service as part of military acculturation. However, little empirical research, within or outside the military, has empirically evaluated how to instill such values effectively and systematically especially among adults.

Conclusion 14: The structure of training and education pathways, up-or-out policies, and mandatory service commitments create a link between promotion and continuous learning and shape motivation for military members to engage in lifelong learning.

Conclusion 15: Because the vast majority of military members ultimately leave the Services and obtain a second career in the civilian sector, military members may be motivated to learn competencies that are transferable to the civilian labor market.

Recommendation 3: Service training and education commands, as well as Professional Military Education institutional leaders, such as commandants, should conduct a systematic analysis to identify gaps in existing military-to-civilian transition services focused on the extent to which competencies developed in the military translate into the civilian labor market. The analysis should also identify areas of overlap in which the military can integrate civilian-based education and certification into its own curriculum.

- **Findings from the analysis described above should be used to develop new approaches to improve support and services for this transition.**

EFFECTIVE LEARNING CONTEXTS

Conclusion 16: Desirable difficulties can optimize the retention of knowledge and competencies, even if they may slow the initial acquisition of knowledge. This general learning principle is applicable through the adult lifespan.

Conclusion 17: In addition to including desirable difficulties where appropriate, optimal learning contexts often have the following characteristics:

- *Active, interactive, and adaptive experiences with linked representations to previously learned competencies, open-ended learner input, and communication with other learners;*
- *Strong support for tailoring learner control to individual learners;*
- *Strong support from policies, practices, as well as leadership and peers;*
- *An overarching feeling of belongingness, especially for minoritized members; and*
- *A psychologically safe environment for individuals and teams to learn and make mistakes when appropriate and safe.*

Conclusion 18: A large portion of learning occurs outside formal learning and education contexts. Capability, awareness, motivation, self-regulation, opportunity, and support are critical for learning in these contexts.

Conclusion 19: The Services conduct systematic needs assessments routinely to inform technical occupational training design and implementation. For the most part, however, the Department of Defense (DoD) has not conducted such analyses to inform what is taught in other DoD learning contexts, including Professional Military Education.

Recommendation 4: Service-specific and Joint Professional Military Education institutions, in coordination with the Military Education Coordination Council as applicable, should identify gaps where systematic needs assessments are not being fully and regularly conducted to guide the design, implementation, and evaluation of educational programs and to better align learning with mission requirements to maximize effectiveness. These assessments should include the consideration of the broader contextual factors and facilitators that may impact implementation.

- **Needs assessments should establish learning activity requirements aligned to course curriculums and objectives. An emphasis should be placed on identifying active and experiential learning through continuous assessment needs to drive optimal outcomes and the transfer of learned competencies outside of the classroom. Findings from needs assessments should be used to modify existing practices when and where necessary.**
- **Develop new measures of competencies, leveraging rigorously developed competency frameworks such as the Army Talent Attribute Framework. Engage and coordinate with Professional Military Education institutions in standard-setting exercises to establish better defined levels of proficiency for each competency across the Department of Defense.**

MILITARY INSTRUCTORS

Conclusion 20: Instructors are a central component of the military learning environment, and they affect overall learning effectiveness. Military instructors have relevant practical and shared experiences with military learners, making them uniquely positioned to support learning. However, as a result of policies and practices, military instructors may have *received limited training in education and have few opportunities for growth because of short, fixed-tenure limitations. These factors can negatively affect student learning.*

RECOMMENDATION 5: Service training and education commands, as well as Professional Military Education institutional leaders, such as service academy commandants, should provide more robust supports for military learning facilitators, including instructors and instructional designers, to minimize barriers, leverage their strengths, and improve the effectiveness of learning by taking the following actions:

- **To improve military instructor quality, and in accordance with mission constraints, identify suitable opportunities to increase instructor tenures and properly reward instructors.**
- **Provide more robust training and professional development about learning principles and best practices in education for all learning facilitators prior to teaching, training, or instructional design assignments. Provide ongoing support and mentorship for learning facilitators during and after they receive this training.**
- **Provide more robust training and support for instructors and other instructional staff on interpersonal skills and socioemotional competencies to maximize their potential as mentors for military learners.**
- **Build a more robust credentialing system to establish a systematic approach for collecting and verifying data regarding learning and development of instructors.**

STRESS AND LEARNING

Conclusion 21: Stress, which military members experience frequently, has the potential to impede or facilitate learning. How individuals appraise their resources and demands informs the type of stress response they will experience. Challenge-type stress responses are generally associated with facilitatory outcomes, while threat-type stress responses are largely harmful. The effects of stress on learning in the military remains a promising area of study.

Conclusion 22: Chronic stress processes, different stress recovery trajectories, and individual mental health conditions may shape the effect of stress on learning.

Recommendation 6: Service training and education commands as well as Professional Military Education institutional leaders, such as commandants, should identify which considerations of stressors need to be incorporated into training and education that meet varied contextual needs to support mission success. This may include, for example, teaching learners to frame stressors as challenges and not threats.

DIVERSITY, EQUITY, AND INCLUSION

Conclusion 23: Surface level characteristics, such as gender and race, can create barriers to learning within the military context, particularly when people are underrepresented within the learning context.

Conclusion 24: Factors associated with diversity, equity, and inclusion can affect learning and performance meaningfully. Several interpersonal factors and negative interpersonal treatment, such as identity-based harassment, can increase a learner's anxiety, which can undermine learning, reduce motivation, and diminish feelings of belongingness. However, most research on these issues is conducted outside of the military. Military environments have unique characteristics that may affect the generalizability of this research.

Conclusion 25: Outside the military context, mentor-mentee similarity can positively affect perceived support and learner outcomes. This is particularly true for experiential and deep-level similarity, which includes malleable factors. The factors that contribute to overall feelings of similarity, and whether such feelings can help minoritized military learners, are not fully understood in the military context.

RECOMMENDATION 7: Department of Defense research institutions, potentially via a collaboration between the Human Systems Community of Interest and the Office of People Analytics, should conduct a systematic analysis of the prevalence and effect of numeric diversity and interpersonal factors of equity and inclusion, specifically in the military learning context, and examine their effects on learning

effectiveness for military learners. This should be done in accordance with privacy-related legal considerations.

- **Department of Defense training and education institutions should use findings from the analysis described above to inform new training and professional development strategies for their instructors and other instructional staff. This may include, for example, promoting psychological safety and a sense of belonging in learning contexts by reflecting on commonalities and shared experiences with their students.**

TECHNOLOGY-ENABLED LEARNING

Conclusion 26: Technology-enabled learning provides significant potential to improve learning effectiveness and efficiency, but to achieve such outcomes the technology needs to be implemented with both empirically supported learning science and engineering best practices.

Conclusion 27: Emerging technologies provide promising opportunities to enhance learning experiences, including new ways to personalize experiences at scale and to optimize outcomes through data-informed methods. However, to use these new technologies effectively, the corresponding system components, such as the people, processes, content, instrumentation, user interfaces, and policies, also need to be designed to facilitate the desired outcomes—before, during, and after the technology-enabled learning experience.

Conclusion 28: Although there are benefits to standalone technology-enabled learning experiences, a systems approach promises greater advantages at organizational and longitudinal scales. A Digital Learning Ecosystem provides the infrastructure by uniting different learning technologies together via interoperable standards, interfaces, and data. Learning engineering processes and practices define the corresponding methods for developing, delivering, and otherwise supporting such experiences.

Conclusion 29: In the military context, practical and cultural limitations are often the largest barriers to optimally employing technology-enabled learning. For example, leaders may procure new technologies without the necessary contextual components or without sufficient implementation considerations. Other limitations include constrained resources, poor understanding of learning science and engineering best practices, lack of user engagement and buy-in, development and acquisition timelines, and Department of Defense policies and regulations.

Recommendation 8: Researchers and developers involved with technology-enabled learning should incorporate the best practices and systematic approaches of Learning Engineering and the Digital Learning Ecosystem concept early in a product's lifecycle, as early as the Applied Research phase (i.e., U.S. Department of Defense "Budget Activity 6.2").

- **Establish repeatable Learning Experience Design principles to support usability and user-experience design and develop repeatable ways to implement these human-centered design methods reliably and efficiently.**
- **Explore and integrate modern data collection methods, such as automated and noninvasive instrumentation, multimodal data fusion methods, and inferential analytics to enable data-informed optimization of learning experience.**
- **Define requirements for analytics (in the context of learning) early, including instrumentation for data collection, standards for data interoperability, and plans (informed by learning science) for using the resulting data to drive meaningful outcomes.**
- **Conduct systematic needs assessments to understand the context of use, people, and processes necessary for effective implementation of technology-enabled learning. Procurements of technology-enabled learning components should also be informed by such analyses. This recommendation applies to technologies as standalone devices within the larger military enterprise. Avoid technology acquisitions that are driven by subjective impressions of a solution's innovative nature.**

- **Researchers and developers should consider the realistic context of use and to design holistic solutions—not only building technology innovations but also designing the other components necessary for their applied use in military contexts.**

Recommendation 9: Department of Defense organizational stakeholders overseeing human-systems research, training, education, personnel, and digital systems (e.g., Army Futures, Naval Education and Training Command, Air Education and Training Command, Marine Corps Training Command, Space Training and Readiness Command, and the Chief Digital and Artificial Intelligence Office) should work concurrently toward implementing a Digital Learning Ecosystem. That ecosystem would include intra- and interoperability, data-informed orchestration, and enterprise analytics across the continuum of learning contexts and experiences throughout individuals' careers.

- **Using a Modular Open Systems Approach, collectively develop shared standards (in conjunction with public consensus standards organizations), enterprise software systems, and the standardized components needed for the technical infrastructure of a Digital Learning Ecosystem.**
- **Establish reliable processes for testing new capabilities using the Digital Learning Ecosystem infrastructure, including methods for rapidly plugging in experimental systems and A/B testing.**
- **While maturing the Digital Learning Ecosystem, also iteratively develop, document, and implement corresponding Learning Engineering practices.**
- **Establish processes for managing the digital artifacts required to enable a Digital Learning Ecosystem, such as interoperable learning activity data interfaces with shareable data profiles representing the learning experiences, competency frameworks based on principles of semantic interoperability, interface standards, multimedia components, standardized object metadata formats, and methodologies for representing learning experiences as part of a summative and authoritative record.**

- **Develop common and aligned frameworks of Department of Defense-wide performance proficiency standards for competencies. These frameworks should facilitate interorganizational content alignment and support technology-enabled learning by serving as referenceable metadata.**

ASSESSMENT AND EVALUATION

Conclusion 30: It is difficult to conceptualize and measure clearly many of the competencies likely to become increasingly important in the future of work, such as 21st century skills. This is especially true in the military context as a result of changes in the operational environment and in technology. Much of the current assessment of hard-to-measure adult competencies relies on self- and informant-report rating scales. These measures are limited because of factors such as halo effects, reference group effects, and socially desirable responding. New performance-based or direct assessment methods, including simulations and games, avoid the drawbacks of rating scales, but they introduce new challenges and have not been researched sufficiently to determine to what extent they might supplement or replace traditional rating-scale methods.

Conclusion 31: Powerful methods to evaluate adult learning and developmental outcomes are available but are generally underused. Considerations for bias, internal and external validity, and designs to support causal inference determine the approaches used for evaluation and assessment.

RECOMMENDATION 10: Professional Military Education institutions, technical training schools, and defense research organizations should provide continued investment in efforts that can support the future of assessment and program evaluation:

- **Invest in the continued promotion of research designs and methodologies to enhance the validity and reliability of evaluation of learning in military contexts, for instance, augmenting support for cooperative research endeavors**

that aim to maximize representation of learners through novel sampling methods.

- **Support best practices in assessment including designs that encompass pretest, posttest, random assignment and control groups where permissible, with attention to transfer of learned skills to performance on the job and return on investment. When such approaches are difficult or impossible to implement, explore alternative quasi-experimental designs. Clearly articulate limitations of a design on causal inferences regarding efficacy findings.**
- **Invest in further development of assessments of hard-to-measure competencies.**
- **Label and retain assessment data, whenever possible, to be used for conducting longitudinal analyses, training machine learning models, and other research applications.**

RESEARCH AGENDA

Basic and applied research on human learning has been a cornerstone of behavioral science for the past century, and the current study features much of this work. However, fewer studies have applied the tenets of adult learning to military members in military contexts as the current report aspires to do. Through its deliberations and review of the literature, the committee identified areas where more research is needed and has organized the following research agenda along four broad themes: (1) understanding the military learner, (2) the military learning context, (3) diversity, equity, and inclusion, and (4) topics related to military effectiveness, such as implementation and assessment. The following describes research goals and examples within these themes that the committee hopes will be useful for the report sponsor, ARI, as well as researchers and funders in setting priorities for the future.

The Military Learner

As this report highlights, military learners are adult learners ranging in age from early adulthood through late midlife who would be expected to experience the shifts in abilities, knowledge, and goals discussed in the report, such as varied knowledge profiles based on prior experience and shifts in goals depending on career stage. Specific research topics include a broad consideration of the goals and motivation of military learners, the competencies they need to learn to be successful in the military context, and how to best design learning contexts for optimal learning. The committee identified many areas of potential research focused on understanding the motivation of military members in the pursuit of learning and development activities, both in terms of the choice to pursue a learning and development goal and a military member's persistence and self-regulation once they have chosen that goal. The identified areas include the following:

- Research reviewed in this report suggests that people are motivated to learn when learning leads to a desired outcome such as a career or job. Furthermore, the committee's findings suggest that military members are not always matched with a job role aligned with their vocational interests. Research is needed to understand how misalignment/alignment between interests and role assignment may affect motivation for learning and development, learning outcomes, and ultimately job performance.
- Because many military members pursue a second career after their military service, it is likely that they will be motivated by the potential transferability of skills learned in the military to civilian contexts. However, there is no research on how the perceived transferability of these skills may motivate military learners to engage in continuous learning while in the military and whether these factors motivate young adults to be recruited into the military. Research is needed on whether the perceived transferability of military skills to the civilian labor market affects motivation for learning in the military. More generally, research is needed to understand the factors that intrinsically and extrinsically motivate military members to pursue learning opportunities. For example, what outcomes do military members value and perceive they can attain through learning activities?
- Research suggests self-efficacy is an important determinant of the choice to engage in learning activities and is part of self-regulation after the choice to engage. However, little research has examined the role of self-efficacy and self-regulation for allocating time for learning activities and for balancing learning across competing demands, such as family and current work role. Given the prevalence of technology-enhanced learning, which increasingly provides informal learning opportunities outside the

classroom, one's self-efficacy to balance life and learning is likely an important determinant of engaging in learning in the military context and an area ripe for future research.

- The competencies needed for success in the military—including 21st century skills related to cognitive, interpersonal, and intrapersonal skills—may require attitude change initiated by learning and development activity. Research is sparse on how best to train these competencies in military and civilian contexts, when military members would benefit most from such training, and the motivation military members might have for learning these skills. Research is needed to develop ways to assess the effectiveness of training in decision making. Specifically, the observe-orient-decide-act loop model is prominent, but it has not been researched empirically.
- Additional research is needed to investigate the cognitive, affective, and self-regulatory processes that contribute to internalization of military core values such as integrity, respect, and selfless service. Researchers should review existing military curricula related to core values to distinguish instructional strategies currently used across DoD, develop measures of internalization of core values (e.g., self- and other-reports, scenario-based measures) where absent, and test the effectiveness of instructional strategies independently to determine how such values can be instilled most effectively in formal and informal learning contexts.

The Military Learning Context

This report highlights research—some specific to military members and other research that is more general—on the features of learning contexts that facilitate or impede learners. In its review, the committee identified several opportunities for further research focused on learning contexts.

Components of the military's culture—such as power distance and respect—create hierarchical structures that may affect the perceived value of learning opportunities and thus motivation for these activities. Hierarchy may also affect learner perceptions of autonomy in selecting what and how they will engage in learning activities, which would similarly affect motivation for learning and development activities. Although some research on autonomy and motivation for learning has been conducted in civilian contexts, the strong cultural aspects of the military, particularly related to hierarchy, may limit the generalizability of these findings, and research within military contexts is needed. Moreover, this research should be conducted within formal and informal learning environments.

Many military environments are volatile, uncertain, complex, and ambiguous. As such, these environments differ greatly from those in which most civilian research on training and learning is conducted. The committee had several recommendations for future research related to the nature of military environments, as follows:

- Research is needed that supports developing new or updated theoretical frameworks focused on stress for military members and how stress may shape learning effectiveness and subsequent future performance. Specifically, research is needed to investigate how to increase the robustness of learning and performance under stress, including identifying best practices for preparing individuals to acquire new information and competencies, as well as those to prepare them to retrieve previously learned competencies under stress. For example, research could aim to understand how or whether to induce stress into learning contexts to optimize learning and operational performance. Research could also examine the best ways to introduce desirable difficulties and active learning interventions, such as error management training in such environments to ensure that military members create durable knowledge structures. Research could also explore the effectiveness of tolerance or coping strategies for stress in multiple formal and informal learning contexts and how to best develop these coping strategies with military members.
- Within military contexts, little is known about how chronic stressors, such as life events, work-life interactions, career, operational contexts, and wartime conditions affect learning and motivation for learning. Similarly, little is known about how mental health conditions, such as post-traumatic stress and depression, may induce stress and affect learning and motivation for learning. The relationship between emotion and learning is another burgeoning area of research that would benefit from additional study.
- Within volatile, uncertain, complex, and ambiguous environments, rapidly changing contexts can easily translate to unforeseen errors. Moreover, in hierarchical contexts, military members may not experience the psychological safety to recognize or call

attention to errors. As such, research examining how perceptions of psychological safety are affected by military culture and the effects of psychological safety on the efficacy of training interventions such as error management training and after-action reviews is warranted.

Formal learning environments, typically in a classroom setting with a human instructor, also present research opportunities in the military context. Specifically, the effects of instructor/student interpersonal dynamics in the military context are not well understood, particularly as they relate to student motivation, persistence, graduation rates, and the overall support of the military mission. Similarly, little is known about how the training and support received by instructors affects teaching performance, expertise, instructor job attitudes, and subsequent student outcomes. Given the wide range of competencies military members must learn throughout their career, and the limited standardized training and professional development for military instructors, instructor development and its impact on student outcomes is a research priority.

Technological advances are quickly changing the way that people learn in both formal and informal contexts, and, when done well, technology-enabled learning has the potential to provide learning experiences adapted to each learner. Personalized learning has the potential to greatly benefit military learners given that the range in age and experience of military learners creates varied individual abilities and learning profiles. Despite the potential benefits, little research exists on the effectiveness of technology-enabled learning in military or civilian contexts. Given the ever-expanding availability of technology-enabled learning tools, the committee identified several areas for fruitful research:

- Research has shown that support factors, such as the work environment, leader, peer, and organization, all play a critical role in facilitating and enhancing learning. Research is needed to understand the role of technology as a support factor. Specifically, does it account for variance above and beyond these other support factors? How does it work in concert with other support factors?
- Research is also needed to understand the best practices on integrating technology to advance stealth assessment—*in situ* assessments that take place during a learning opportunity.

- New or refined theoretical models and conceptual frameworks should also be developed that focus on the emergence of human-robot teams and how the effectiveness of adult learning in the military may or may not be affected.

Research is also needed to examine generative artificial intelligence (AI) functions paired with Digital Learning Ecosystems to optimize self-directed learning requirements such as learner-initiated, usually informal, learning activities. This includes theoretical research examining augmented intelligence in the context of self-regulation and metacognition, and experimentation looking at tools and methods to create, enhance, supplement, and personalize learning experiences in a self-directed context.

Researchers should also explore new theoretical frameworks of self-regulated learning with the incorporation of generative AI tools and methods that leverage large language models and conversational agents to support learning objectives. This incorporates augmented intelligence paradigms that account for the use of technology, account for the limitations in cognition and prior knowledge, and emphasize learning best practices. These models could be developed and deployed in both informal and formal learning contexts. Additional research questions on AI and learning include the following:

- How can AI support learner's goal-setting processes, self-monitoring abilities, and metacognitive strategies in informal and formal learning environments?
- How can emerging capabilities in AI and large language models tailor, automate, or generate training content for individual learners? This is a particularly important research consideration given the wide array of ages and experiences in the military, contributing to varied profiles of prior knowledge and skills. One question that may arise, for example, is related to the optimal balance between automation and human oversight in the content creation process.
- How might emerging capabilities in AI and large language models tailor, automate, or generate immersive scenarios for team learning?
- Despite the known benefits of team training for team members in general, the existing theoretical models were developed based on teams of humans and were not developed in the military context. However, with advances in technology that allow for greater human-robotics and human-AI teaming, research is needed to establish methods for assessing and evaluating the effectiveness of human-nonhuman teams.

- How might psychometric considerations be incorporated into AI generated content? This may include forms of modern, transparent assessments across the various learning contexts and should include considerations of inferential, latent factors and multi-factor data. For example, researchers can explore the use of generative AI to create hyper-personalized learning content and assessments, to potentially include unique items tailored to individuals. This work must also explore questions such as reliability, validity, equivalency, and accountability.

Diversity, Equity, and Inclusion

Diversity, equity, and inclusion affect military learners and the context in which they learn. The committee identified several areas of necessary research to fully understand the extent to which diversity, equity, and inclusion issues facilitate or impede learning in military contexts. First, researchers can examine the person-environment fit's role throughout a military career and its effect on learning. In particular, research should determine how a military member's sense of belonging and deep-level similarity affect motivation for and performance in learning activities. It is also imperative to understand how the military context—including the unique culture of the military and the demographic make-up of peers and instructors—affects a military member's sense of belonging and feelings of deep-level similarity, particularly for minoritized military members. Interventions can then be developed, deployed, and evaluated to increase military members' sense of belonging.

Second, research is needed to develop and identify potential interventions to support diverse military learners. For instance, research is needed to fully explore the potential effect of gender or racial/ethnic similarities in instructors and students and whether matches in gender or in race/ethnicity characteristics can help promote learning outcomes for underrepresented military learners.

Military Effectiveness

The committee decided that some areas of future research should focus on military effectiveness, rather than individual learners or the learning context. Specifically, these topics are related to overall efforts to better assess and measure the impacts of military training and technological advances that more directly affect institutional effectiveness.

Additional research should be conducted on the use of new, interactive, and experiential methods for assessing and evaluating the hard-to-measure competencies that are likely to become increasingly important in the future world of work—including 21st-century skills, such as curiosity, teamwork, creativity, and self-regulation. Research is also needed to examine how to collect data from multimodal sources during training events and integrate them post-event to support individual learners with using technologies. For instance, this may include collecting and integrating neurological, attitudinal, and performance data and providing formative and summative assessments. Similarly, research should include approaches to modeling the growth and development of competencies. In all cases, attention should be given to the best psychometrics measurement, analysis, standard-setting, and reporting practices. In addition, this work should include learning analytics, considering such factors as instrumentation, multimodal fusion of data, and longitudinal analyses.

Research can also be conducted to determine how to use technology to integrate and compare existing competency models. Research is needed to establish doctrine in digital artifacts that represent competency frameworks—knowledge, skills, and behaviors—required for expert proficiency aligned to an occupational specialty and the tasks executed in their mission role(s). This includes doctrinally informed artifacts for individual and team task requirements. Learning resources and training environments can then align with these frameworks to establish data-driven multi-environment chains of evidence for objective approaches to modeling competency progression and readiness.

Research is needed to connect multimodal data analytics performed at the individual learning-event level with multi-environment data analytics performed at the ecosystem level to quantify the impact of learning resources on outcomes in high-stakes evaluation events. Longitudinal studies are needed to better understand how simulation and extended-reality modes of learning directly support competency requirements in an operational environment. Longitudinal studies are needed to establish mathematical models of task proficiency and expertise to better understand the optimal use of technology-enabled learning to drive the development of expert teams.

Research is also needed to address standard competency and metadata definitions for experiential-focused outcomes, mathematical modeling techniques to accurately quantify probabilistic representations of competency, and user interfaces and visualization to effectively communicate this information to various roles supporting learning needs.

Appendix A
Biographical Sketches

COMMITTEE MEMBERS

MARGARET E. BEIER *(Chair,* she/her/hers*)* is a professor of industrial and organizational psychology and chair of the Department of Psychological Sciences at Rice University. She is a leading expert on workplace aging and retirement. Beier's research examines the influence of age, motivation, skills, and abilities on success in organizations, particularly related to the factors that contribute to lifelong learning and development. Her research has been funded by the National Science Foundation and published in major academic outlets including the *Journal of Applied Psychology*, the *Journal of Business and Psychology, Psychology and Aging*, and *Psychological Bulletin*. Beier is a fellow of the Society for Industrial and Organizational Psychology and a fellow of the Association for Psychological Science. She obtained her undergraduate degree at Colby College in French literature and her masters and doctoral degrees in psychology at the Georgia Institute of Technology. She has participated in two National Research Council committees: How People Learn II: Learners, Contexts, and Cultures and Are Generational Categories Meaningful Distinctions for Workplace Management?

LAURA G. BARRON (she/her/hers) currently works in the U.S. Air Force's Air Education and Training Command where she conducts enterprise-wide research and assessment to support force development and diversity, equity, and inclusion. Her recent projects have addressed Professional Military Education for Joint Staff officers; Junior Reserve Officer Training Corps instructor recruitment; training and squadron-level practices to support Diversity, Equity, and Inclusion; as well as foundational military training on information literacy. Barron previously worked as a personnel research psychologist and chief of strategic research & assessments at the Air Force Personnel Center supporting the selection and classification of Air Force personnel. Prior to entering public service, she worked as an assistant professor in the University of Wisconsin system. Barron has authored more than 30 peer-reviewed articles on topics such as workplace diversity, training development, and military personnel selection that have been published in journals such as *Military Psychology*, *International Journal of Selection & Assessment*, *Human Performance*, and *Psychology*, *Public Policy & Law*. She holds a masters and doctoral degree in industrial and organizational psychology from Rice University.

ROBERT A. BJORK (he/him/his) is distinguished research professor of psychology at the University of California, Los Angeles (UCLA). He has served as chair of UCLA's Department of Psychology, as editor of both *Memory and Cognition* and *Psychological Review*, as well as co-editor of *Psychological Science in the Public Interest*. He is past-president or chair of the Association for Psychological Science, the Psychonomic Society, and the Society of

Experimental Psychologists. He is a recipient of UCLA's Distinguished Teaching Award, the American Psychological Association's Distinguished Service to Psychological Science and Distinguished Scientist Lecturer Awards, and the Mentoring Award from the Association for Psychological Science. He is a member of the National Academy of Sciences and the American Academy of Arts and Sciences. He chaired the National Academies' Committee on Techniques for the Enhancement of Human Performance.

SHERNETTE D. DUNN (she/her/hers) is currently the Communication Specialist at Air University at Maxwell Air Force Base. In this role she provides professional developmental opportunities for new faculty and professional communication support to cadets, officers, and enlisted military personnel who are working on graduate military education degrees. Her research interest includes culturally responsive teaching for online learners, adult education, motivation, instructional technologies, learners with disabilities, and student success initiatives. Dunn is a member of several education related professional organizations such as Society for Information Technology in Teacher Education, and National Organization for Student Success to name a few. She has won numerous awards for her contributions to promoting student success and equity and diversity in one of our nation's top military institutions. Dunn was the winner of her base's Blacks in Government Award and continues to leave her mark on the lives of cadets and staff and works to contribute to the long blue line. She earned her bachelor's in elementary education and English for speakers of other languages, master's in reading education, specialist in educational leadership, and a doctoral degree in adult education and instructional technology at Florida Atlantic University.

ARMANDO X. ESTRADA (he/him/his) is a professor of Policy, Organizational and Leadership Studies at Temple University. His research examines factors influencing diversity, inclusion and engagement; prejudice, harassment and discrimination; cohesion, resilience, readiness, and effectiveness within organizational settings. He has led, administered, and managed academic programs in leadership education and development; executive and strategic leadership; experimental psychology; and adult and organizational development at various institutions including the U.S. Naval Academy; U.S. Naval Postgraduate School; The National Defense University; Washington State University; and Temple University. He routinely provides leadership support, research and technical advice to working groups and taskforces in the National Security and Defense sector in the US and partner nations. He is a fellow of several societies but most notably the Society for Military Psychology, where he served as the first graduate student representative, chair of the membership committee, member at large, president, and editor in chief for Military Psychology. He received the Charles S. Gersoni Award for Excellence in Military Psychology and the John C. Flanagan Award for Lifetime Achievements in Military Psychology from the American Psychological Association Division 19 Society for Military Psychology. After serving in the United States Marine Corps, he earned his bachelor's and master's in psychology from the California State University at Los Angeles and his doctoral degree in industrial and organizational psychology from the University of Texas at El Paso.

BENJAMIN S. GOLDBERG (he/him/his) is a senior research scientist at the U.S. Army Combat Capability Development Command—Soldier Center where he serves as technical lead for a research program focused on the development and evaluation of adaptive Training Management Tools for future Army training systems. His research focuses on adaptive experiential learning with an emphasis on simulation-based environments and leveraging

Artificial Intelligence to create personalized experiences. This involves exploring research questions linked to intelligent tutoring, competency development, persistent learner modeling, immersive interaction, mixed reality, and user experience. Goldberg's research aims to impact how technology can be applied to support the development and sustainment of expertise in challenging domains that require proficiency across cognitive, psychomotor, and affective knowledge and skill sets. He has researched adaptive instructional systems and intelligent tutoring for the last 15 years. Goldberg is well published across several high-impact journals and proceedings, including *IEEE Transactions of Learning Technologies*, the *Journal of Artificial Intelligence in Education* (AIED), and *Computers in Human Behavior*. He also served as past-chair on the Extended Reality Technical Group within the Human Factors & Ergonomics Society and sits on several conference program committees including AIED and the Interservice/Industry Training, Simulation and Education Conference. Goldberg is co-creator of the Generalized Intelligent Framework for Tutoring and received the Education and Human Performance Award administered by the National Training and Simulation Association. He holds a doctoral degree in Modeling & Simulation from the University of Central Florida.

PATRICK C. KYLLONEN (he/him/his) is a distinguished presidential appointee at the ETS Research Institute. He conducts research on assessment and psychometric modeling of human skills, such as reasoning and collaborative problem solving, and personality, attitudes, values, and beliefs. Kyllonen has co-authored *Generating Items for Cognitive Tests* (with S. Irvine, 2001); *Learning and Individual Differences* (with P. L. Ackerman & R. D. Roberts, 1999); *Extending Intelligence: Enhancement and New Constructs* (with R. Roberts and L. Stankov, 2008); and *Innovative Assessment of Collaboration* (with A. von Davier and M. Zhu, 2017). He is a fellow of American Psychological Association and American Educational Research Association. Kyllonen received a bachelor's from St. John's University and a doctoratal degree from Stanford University. He has co-authored the following National Academy of Sciences reports: "Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century" (2012), "Measuring Human Capabilities" (2015), and "Supporting Students' College Success: The Role of Assessment of Intrapersonal and Interpersonal Competencies" (2017).

MICHAEL W. NATALI is a lieutenant commander in the Navy and a program officer for the Office of Naval Research where he manages the Manpower, Personnel, Training, & Education research portfolio focused on optimizing Sailor performance by improving manpower modeling, personnel screening, training effectiveness, and educational opportunities. He previously served as the Deputy, Air Warfare Training Development lead for Naval Aviation Training Systems & Ranges integrating emerging technologies to enhance aircraft systems, training, and processes; department head for Human Performance & Research for the Chief of Naval Air Training improving training methodologies and assessment; and as the BioStatistics Division Officer for the Naval Aerospace Medical Institute managing the Navy's Aviation Selection Test Battery. Natali's work has been widely recognized, receiving the Assistant Secretary of the Navy for Research, Development and Acquisition's Dr. Delores M. Etter Top Scientists & Engineers Team Award; the Society for Industrial and Organizational Psychology's Distinguished Early Career Award—Practice; the 2023 American Psychological Association Division 19 Society for Military Psychology Juluis E. Uhlaner Award; the Naval Air Warfare Center Training Systems Division's Admiral Luis de Florez Training & Simulation Award; the Captain Sonny Carter Memorial Award; and the U.S. Navy Aerospace Experimental Psychology

Society Robert S. Kennedy Award. He joined the Navy as an aerospace experimental psychologist and his expertise covers personnel selection, training systems and evaluation, performance measurement, and human-systems integration within military settings. Natali completed his doctorate in industrial and organizational psychology at University of Minnesota while also working as a research consultant for Assessment Associates International.

AARON R. PHIPPS (he/him/his) is an assistant professor of economics at West Point, where he also contributes to research for the Army's Office of Economic and Manpower Analysis. He specializes in labor economics, economics of education, and personnel economics. Phipps' research focuses on using incentives to improve education and measuring the returns on educational investments. He has been recognized for his teaching and scholarly accomplishments. Phipps has been the recipient of several honors, including the Institute of Education Sciences Predoctoral Fellowship, Predoctoral Bankard Fellowship from the University of Virginia, Department of the Army Civilian Service Achievement Medal, West Point's Murdy Teaching Award, and the Upjohn Institute's Early Career Research Award. He received his doctorate in economics from the University of Virginia.

EDUARDO SALAS is the Allyn R. & Gladys M. Cline Professor of the Department of Psychological Sciences at Rice University. He has a 40-year proven track record for developing evidence-based principles, guidance, tools and interventions to improve teamwork, learning and safety across a wide variety of contexts such as aviation, oil and gas, military, emergency response, space exploration as well as healthcare. Salas is a past president of the Society for Industrial/Organizational Psychology (SIOP) and the Human Factors and Ergonomics Society (HFES), Fellow of the American Psychological Association, the HFES and Association for Psychological Science (APS), and a recipient of the Meritorious Civil Service Award from the Department of the Navy. He received the Society for Human Resource Management Losey Lifetime Achievement Award, the Joseph E. McGrath Award for Lifetime Achievement from the INGroup, the Distinguished Professional Contributions & 2016 Distinguished Scientific Contributions Award, a four-time winner of the M. Scott Myers Award for Applied Research in the Workplace, and the Wayne Casio Scientist-Practitioner Award, all awarded by SIOP. Salas received the James McKeen Cattell Fellow Award for outstanding lifetime contributions to the area of Applied Psychological Research from the APS and the American Psychological Foundation Gold Medal Award for Impact in Psychology.

SAE SCHATZ (she/her/hers) is the executive director of the Partnership for Peace Consortium of Defense Academies and Security Studies Institutes. Formerly, she directed the Pentagon's Advanced Distributed Learning program. She has also worked as a chief scientist in industry and held an assistant professorship with the University of Central Florida's Institute for Simulation and Training. Her subject-matter expertise rests at the intersection of humans and cognition, technology and data. Schatz is a prolific writer and professional presenter. She co-authored *Engines of Engagement: A Curious Book About Generative AI* (2023), co-edited *Modernizing Learning: Building the Future Learning Ecosystem* (2019) and has been published in the *Journal of Military Learning, Journal of Defense Modeling and Simulation,* and *Military Psychology*. Schatz holds a doctorate in modeling and simulation, with an emphasis on human systems.

ELIZABETH A. L. STINE-MORROW (she/her/hers) is a professor emerita and research scientist in the Department of Educational Psychology and the Beckman Institute at the

University of Illinois. Her research is broadly concerned with the multifaceted nature of adult development and aging, and factors that support the maintenance and growth of cognition and learning through the adult lifespan. This work has examined how self-regulated adaptations (e.g., selective allocation of attentional resources, reliance on knowledge-based processes, activity engagement) impact cognitive abilities and everyday performance through adulthood. Much of Stine-Morrow's research has focused on the important role of literacy and the processes through which effective reading is maintained into late life. This research has been funded by the National Institute on Aging, the National Science Foundation, and the Institute of Education Sciences. She is a fellow of the American Psychological Association (APA; Division 20), the Association for Psychological Science, the Gerontological Society of America, and the Psychonomic Society, and was the recipient of the APA Division 20 Mentorship Award. Stine-Morrow has served as associate editor for the *Journal of Gerontology: Psychological Science* and for *Memory & Cognition*; she currently serves as editor for *Psychology and Aging*. She received her doctorate from Georgia Tech in general-experimental psychology, with a focus in cognitive aging, and was a postdoctoral fellow at Duke University. She was a member of the National Academy of Sciences' Committee on Learning Sciences: Foundations and Application to Adolescent and Adult Literacy.

MIKHAIL A. WOLFSON is an associate professor and Vernon Smith fellow in management at the University of Kentucky. He was previously an assistant professor in Kogod School of Business at American University. Wolfson's research expertise includes informal learning, team composition, human capital resources, multilevel modeling, network analysis, and unobtrusive measurement. Primarily his research focuses on advancing configural approaches of team composition that account for individuals' characteristics and interrelations among team members. Wolfson has conducted research in the contexts of the U.S. Military (Army, Navy, Marine Corps), surgical teams, intensive care unit teams, professional cycling, and student teams. Additionally, he has experience working with the U.S. Military on grant research funded by the Department of Defense through the Army Research Institute, and U.S. Army Medical Research and Development Command, Military Operational Medicine Research Program. His research has been published in major academic outlets including the *Academy of Management Journal, Journal of Applied Psychology*, and *American Psychologist*. Wolfson is a member of the Academy of Management, the Society of Industrial and Organizational Psychology and has received awards for his research and teaching from the University of Connecticut, American University, and the University of Kentucky. He earned his bachelor's in psychology at the University of Massachusetts and his doctorate in business administration from the University of Connecticut.

STAFF MEMBERS

EMILY A. VARGAS (*Study Director*, she/her/hers) is a program officer with the Board on Behavioral, Cognitive, and Sensory Sciences at the National Academies of Sciences, Engineering, and Medicine. She worked as a staff member on the recently released National Academies' report, "Advancing Antiracism, Diversity, Equity, and Inclusion in STEMM: Beyond Broadening Participation". Vargas' expertise is focused on the intersection of individual's marginalized identities and psychosocial factors, and how they impact well-being as well as inform disparities and equity. Prior to joining the National Academies, she worked at

Northwestern University as a research assistant professor in preventive medicine. Vargas earned her B.A. with honors in Psychology from Rutgers University, with her master's and doctorate in psychology from the University of Michigan in personality and social contexts. After graduation, she completed a two-year T32 Postdoctoral Research Fellowship in Cardiovascular Disease Epidemiology and Prevention at Northwestern University, Feinberg School of Medicine.

SHARON BRITT (she/her/hers) is the program coordinator for the Board on Behavioral, Cognitive, and Sensory Sciences. She previously worked at Howard University Hospital as a program coordinator with the Graduate Medical Education Department. In this position, Britt managed the Orthopedic and Podiatric Surgery Residency program that prepares residents to succeed in their practice locations and specialties and provides high-quality care. Prior to her position as the residency coordinator, she worked on several government contracts as a Helpdesk Manager and IT Analyst. She graduated from Strayer University with a bachelor's in business administration.

KATHERINE R. KANE (she/her/hers) is a research associate for the Board on Behavioral, Cognitive, and Sensory Sciences at the National Academies of Sciences, Engineering, and Medicine. She previously was a senior program assistant for the Board on Environmental Studies and Toxicology at the National Academies. Kane has worked as an environmental health manager in the Environmental Surveillance & Oversight Program for the South Carolina Department of Health and Environmental Control, a research assistant in the Harmful Algal Bloom Lab at Harbor Branch Oceanographic Institute, and owner of Barn Kat Services, LLC. She graduated from the University of South Carolina with a bachelor's in environmental science and sustainability.

HEIDI SCHWEINGRUBER (she/her/hers) is the director for the Board on Science Education at the National Academies of Sciences, Engineering, and Medicine. In this role, she oversees a portfolio of work that includes K–12 science education, informal science education and higher education. Schweingruber joined the National Academies starting as a senior program officer for the Board of Science Education. In this role, she directed or co-directed numerous projects including the study that resulted in the report "A Framework for K–12 Science Education" (2011) which served as the blueprint for the Next Generation Science Standards. Most recently, she co-directed the study that produced the report "Call to Action for Science Education: Building Opportunity for the Future" (2021). Schweingruber is a nationally recognized leader in leveraging research findings to support improving science and science, technology, engineering, and medicine education policy and practice. She holds a doctoral degree in psychology and anthropology, and a certificate in culture and cognition from the University of Michigan.

AMY STEPHENS (she/her/hers) is the associate board director for the Board on Science Education at the National Academies of Sciences, Engineering, and Medicine. She has served as study director for several consensus studies on a variety of topics to include English learners in science, technology, engineering, and mathematics (STEM) subjects, preschool through elementary science and engineering education, the teacher workforce, and how STEM opportunities can cultivate interest and the development of competencies for computing. She is currently directing the congressionally mandated study on PreK – 12 STEM Education Innovations. Stephens is also an adjunct professor for Southern New Hampshire University teaching online graduate courses in statistics, research methods, cognitive psychology, and cognitive neuropsychology. She has an extensive background in behavioral and functional neuroimaging techniques and has examined a variety of different populations spanning childhood through adulthood. Prior to joining the National Academies, Stephens was a postdoctoral fellow for the Johns Hopkins University's Center for Talented Youth and prior to that worked at the Kennedy Krieger Institute. She received her doctoral degree in psychological and brain sciences from Johns Hopkins University with an emphasis in cognitive neuroscience.

DANIEL J. WEISS (he/him/his) is the director for the Board on Behavioral, Cognitive, and Sensory Sciences at the National Academies of Sciences, Engineering, and Medicine. Prior to joining the National Academies, he served as a professor of psychology and linguistics at Penn State for nearly two decades. Weiss' research focused on the processes underlying language acquisition and motor planning in children, adults, and nonhuman primates. He has also been serving as the editor-in-chief for Translational Issues in Psychological Science. Weiss received his B.A. from the University of Maryland at College Park and his master's degree and doctoral degree from Harvard University. After graduation, he became a postdoctoral fellow at the University of Rochester in the Brain and Cognitive Sciences program prior to his appointment at Penn State University.

Appendix B
Glossary

Active Learning
those that require a learner to construct their own understanding of the to-be-learned content.

Competencies
a broad range of skills, knowledge, behaviors, and attitudes intended to be learned in the military.

Desirable Difficulties
the specific conditions of training or practice that create a sense of challenge for learners generally associated with effective learning outcomes.

Education
the broader preparation (e.g. intellectual and character development) for unknown future situations.

Force Readiness
the ability of military forces to meet demands and fight in assigned missions.

Formal Learning
any training or learning opportunities that provide structured, instructor- controlled environments with explicit curricula and learning objectives (often following a hierarchical model where an instructor or educational technology directs the delivery of content.

Hard Skills
skills that are more tactical, cognitive, or technical in nature.

Informal Learning
learning that is largely unstructured, such as learning on-the-job.

Interoperability
the supported connections across various learning activities.

Learning
the engagement in mental processes that results in the acquisition of new competencies such as skills, knowledge, and attitudes. Learning incorporates the retention of these new competencies over time and includes the application of new competencies in a needed context.

Learning Engineering
an emerging multidisciplinary field that integrates the learning sciences with human-centered design methodologies, engineering principles, data analytics, and organizational performance strategies to optimize learning experiences and outcomes.

Military Member
a uniformed military person.

Professional Development
opportunities designed to maintain and improve personnel capacity. It is intended to open pathways for career advancement within an occupation.

Reliability
is the extent to which [test scores] are consistent across different occasions of testing, different editions of the test, or different raters scoring the test taker's responses.

Soft Skills
interpersonal and intrapersonal skills, and attitudes.

Self-Directed Learning
learning that enables individuals to guide their desired learning outcomes and goal-directed activities over time.

Technology-Enabled Learning
the breadth of technologies used for education, training, informal learning, instructional design, testing, and assessment.

Training
the preparation of personnel to perform specific tasks or meet known job performance requirements.

Validity
the degree to which evidence and theory support interpretations of test scores entailed by proposed uses of tests. It is the interpretations of test scores required by proposed uses that are evaluated, not the test itself.

Appendix C
Supplementary Information on Military Learning Pathways

TABLE C-1 Minimum Requirements for Air Force Promotion Eligibility (as of January 2020)

	Occupation-Specific Requirement	**Minimum Time in Grade**	**Minimum Time in Service**	**Professional Military Education Required For Promotion**
E-2	N/A	6 months	N/A	N/A
E-3	N/A	6 months	N/A	N/A
E-4	Apprentice	8 months	1 year	N/A
E-5	Journeyman	12 months	4 years	Airman Leadership School: 24-day in-residence course or offered via distance learning
E-6	Craftsman	24 months	6 years	N/A
E-7	Craftsman or Superintendent	24 months	8 years	NCO Academy: 6-week in-residence course or offered via distance learning
E-8	Superintendent	24 months	11 years	SNCO Academy: 6.5-week in-residence course or offered via distance learning
E-9	Superintendent	24 months	14 years	Chief Master Sergeant Orientation Course (COC)

SOURCE: *CFETP 2A9X1X*, U.S. Department of the Air Force (2023); *AFI 36-2502,* U.S. Department of the Air Force (2019).

TABLE C-2 Desired Outcomes of Senior Professional Military Education, Including Joint Learning Areas and Desired Leader Attributes

Joint Learning Area (JLA)	Desired Leader Attributes (DLA) and Professional Military Education Outcomes
JLA #3: The Continuum of Competition, Conflict, and War • Are experts in the theory, principles, concepts, and history specific to sources of national power, the spectrum of conflict and the art and science of warfighting. • Apply their knowledge of the nature, character, and conduct of war and conflict, and the instrument of national power, to determine the military instrument across the full spectrum of conflict to achieve national security objectives. **JLA #4: The Security Environment** • Effectively and continuously assess the security implications of the current and future operational environment. • Using appropriate inter-disciplinary analytical frameworks, evaluate historical, cultural, political, military, economic, innovative, technological and other competitive forces to identify and evaluate potential threats, opportunities, and risks.	• **DLA #1**: Understand the security environment and contributions of all instruments of national power • **Professional Military Education Outcome #1**: discern the military dimensions of a challenge affecting national interest; frame the issue at the policy level; and recommend viable military options within the overarching frameworks of globally integrated operations • **Professional Military Education Outcome #2**: anticipate and lead rapid adaptation and innovation during a dynamic period of acceleration in the rate of change in warfare under the conditions of great power competition and disruptive technology
JLA #5: Strategy and Joint Planning • Apply knowledge of law; policy; doctrine; concepts; processes; as well as systems to design, assess, and revise (or sustain risk); resource-informed strategies; and globally integrated, all-domain joint plans across the spectrum of conflict. • Demonstrate a broad understanding of joint, interagency, intergovernmental, and multinational capabilities and policies to inform planning. • Envision requisite future capabilities and develop strategies and plans to acquire them. Use strategy and planning as primary tools to develop viable, creative options for policy makers. Position the United States to achieve national objectives across the full spectrum of conflict.	• **Professional Military Education Outcome #3**: conduct joint warfighting, at the operational to strategic levels, as all-domain, globally integrated warfare, including the ability to integrate allied and partner contributions • **Professional Military Education Outcome #4**: are strategically-minded warfighters or applied strategists who can execute and adapt strategy through campaigns and operations

<u>JLA #6: Globally Integrated Operations</u> • Creatively apply U.S., allied, and partner military power to conduct globally integrated, all-domain operations and campaigns. • Exercise intellectual agility, demonstrate initiative, and rapidly adapt to disruptive change across all domains of competition, conflict and war. They do so consistent with law and the shared values of the profession of arms in furtherance of U.S. national objectives.	• **<u>DLA #2</u>**: Anticipate and respond to surprise and uncertainty • **<u>DLA #3</u>**: Recognize change and lead transitions

SOURCE: Committee generated, text verbatim from *CSJCI 1800.01F*, U.S. Joint Chiefs of Staff (2020).