Adaptability for Human Performance Excellence: Updating the Conceptual Model of Expertise for the Modern Work Environment

Coreen M. Harada & Ashley N. Inbody
Science Applications International Corporation (SAIC)
Reston, VA
coreen.m.harada@saic.com, ashley.n.inbody@saic.com

ABSTRACT

Three industrial revolutions shaped the modern world: the steam engine, assembly line, and digital technology. We are now in the midst of the fourth – the convergence of physical and technological worlds. Up to now, individuals have fulfilled roles based on a prescribed, relatively narrow level of expertise; successful adaptation to modern workplace systems and bridging the gap between existing and future needs requires a shift from rigid, task-specific training to flexible, adaptive skillset development (World Economic Forum, 2018).

Traditional, pre-convergence models of expertise conceptualize development from novice to expert as a function of learning over time, where high level expertise may be obtained with sustained effort and performance feedback (Chi, 2006; Dreyfus & Dreyfus, 1980; Ericsson & Lehmann, 1996; Hoffman, 1998). Much attention is given to observable performance, with far less concern about the thought processes underlying the behavioral outcome. For example, performers may be seen as improving when they incur fewer errors, increase accuracy, and decrease response time (Chi, 2006; Dreyfus & Dreyfus, 1980; Hoffman, 1998). Not accounted for are discrete improvements that may be applicable beyond the task at hand, such as increased knowledge, emotional regulation, use of metacognitive skills, and decreased cognitive load (Eccles & Feltovich, 2008).

The modern workplace system has evolved beyond predictable task-based proficiency; to thrive in today's world, individuals must be able to adapt to novel challenges and demands. This requires adaptive expertise, which involves the successful application of acquired skills to new arenas and represents an extension beyond most existing training efforts and proficiency measures.

This paper presents a conceptual model for designing training that supports adaptive expertise through metacognitive skill development. The model has been developed and tested with U.S. Army Soldiers and proposes a method for the identification and integration of domain-specific metacognitive skills within an existing training framework. This paper also describes prospective approaches to leverage an empirical understanding of metacognitive skills to augment Service Member development and effective performance in real-world, novel settings.

ABOUT THE AUTHORS

Coreen M. Harada, Ed.D. is a behavioral scientist and program evaluator at SAIC. Her work includes randomized trials assessing performance psychology training in the military and she is an expert in training efficacy, implementation science, and science transition. Previously, Dr. Harada was co-director of the Special Olympics Global Collaboration Center, a research institute funded by Special Olympics, Inc., and the U.S. Centers for Disease Control and Prevention.

Ashley N. Inbody, M.S. is a behavioral scientist and analyst at SAIC. Her work includes mixed methods studies assessing training efficacy in the military and developing program evaluation protocols for performance psychology training initiatives. Previously, Ms. Inbody was a Training & Operations Analyst for the US Army's Comprehensive Soldier & Family Fitness program.

Adaptability for Human Performance Excellence: Updating the Conceptual Model of Expertise for the Modern Work Environment

Coreen M. Harada & Ashley N. Inbody
Science Applications International Corporation (SAIC)
Reston, VA
coreen.m.harada@saic.com, ashley.n.inbody@saic.com

INTRODUCTION

Adaptive expertise has been described as "the ability to apply, adapt, and otherwise stretch knowledge so that it addresses new situations – often situations in which key knowledge is lacking" (Wineburg, 1998, p.321). Adaptive expertise is not dependent on knowledge alone but on how it is used. Adaptive experts have "specific cognitive dispositions that augment and enhance the ability to effectively utilize and extend content knowledge" (Fisher & Peterson, 2001, p.1). 'Cognitive dispositions' is a broad term used to describe the heuristics and processes underlying contextual processing and decision making (Croskerry, 2005); it is these trainable underlying processes that allow adaptive experts to orient existing knowledge to the problem at hand without being formally trained to do so.

Historically, military training has focused on delivering domain-specific knowledge and skills; proficiency on technical skill is assessed through set tasks, conditions, and standards. However, achieving standardized goals within known parameters only validates performance reliability in a narrow range of training environments; to succeed in the emerging operational landscape the military must invest in training and education which produces ready, flexible, and fast-thinking Service Members able to maneuver adeptly in complex environments. Training then must be designed not only to develop technical skills but to also equip Service Members with the metacognitive skills underlying adaptive expertise to ensure personal readiness and performance reliability in unpredictable operating environments.

MILITARY TRAINING PARADIGM

Training and education in the U.S. military takes many forms and has immeasurable variability; however, three elements are consistently present in any formal training environment: a student, an instructor, and training content. These three elements represent potential avenues to evaluate and improve training and education. As an all-volunteer force, it is not possible to focus recruiting efforts on identifying individuals who already possess the technical or cognitive qualities of an adaptive expert. It is equally impractical to screen and select instructors based on their ability to develop adaptive expertise in students. First, instructors are assigned based on relevant experience and training program needs rather than being interviewed and hired depending on pedagogical prowess; and second, human performance research has found that domain experts are not always ideally suited for instruction (Kalyuga, 2007). For domain experts, knowledge and skills have become innate, tasks are performed with automaticity, and their performance is so second-nature that it is not communicable to the student. The most practical and efficient conduit then for incurring change is addressing training program content.

Recognizing this and to promote generalizability, the present study was designed to inform training content through two initiatives: 1) identify a general model of expertise development applicable across Army specialties; and 2) to develop and test a methodology for identifying domain specific metacognitive skills underlying progression from novice to expert. The results of these efforts not only reinforce the applicability of human performance and cognitive science scholarship for the military but also support domain general metacognitive skills training as a means to accelerate expertise progression and improve training outcomes towards the level of cognitive, physical, and technical dominance required for modern warfare.

UNDERSTANDING EXPERTISE

Expertise is often defined in terms of observable outcomes – the reliable, seemingly effortless successful execution of a task. To identify a general model of expertise development for an Army training setting, this effort began by evaluating validated, continuum-based expertise models. Validated models of expertise track development in varying numbers of intervals from a naïve or novice (i.e., someone with minimal domain exposure) to an expert or master (i.e., someone able to effectively solve complex problems in a specific field); each model supports the notion that expertise development entails both behavioral and cognitive changes (Chi, 2006; Dreyfus & Dreyfus, 1980; Hoffman, 1998; O'Neil, et al., 2014).

Behavioral changes that can be observed as one moves from novice toward expert include fewer errors, improved accuracy, and decreased response time to external inputs (Chi, 2006; Dreyfus & Dreyfus, 1980; Eccles & Feltovich, 2008; Hoffman, 1998). Cognitive changes that occur as one develops expertise can include decreased cognitive load, increased knowledge, increased emotional regulation, and increased or tailored use of metacognitive skills (also termed 'psychological support skills') such as imagery (Eccles & Feltovich, 2008; O'Neil, et al., 2014). Table 1 offers an example of the main proficiency intervals within a military context.

Table 1. Summarized Model of Expertise Development (Adapted from Chi, 2006 & Hoffman, 1998)

Phase & Definition	Military Training Example
Novice: Someone who is new – a probationary member with minimal exposure to the domain.	Initial Entry Trainee; minimal knowledge of military drill and ceremony, little if any exposure or competency in military operational specialty (MOS)-specific skills. Relies on senior leaders for instruction, direction, and correction to complete tasks to standard.
Initiate: A novice who has been through an initiation period and has begun introductory instruction.	Successful completion of initial entry training (IET); newly assigned to operational unit. Basic understanding of military operating procedures and sufficient competency in MOS-specific skills. Frequently needs direction and clarity for how to complete tasks in an operational environment.
Apprentice: One who is learning – a student undergoing a program of instruction beyond the introductory level. Immersed in the domain and mentored by an individual with more expertise.	Demonstrates competency and responsibility to complete tasks with general supervision. Continues developing skills by partnering with their first-line supervisor. Begins to consider mentoring/leading others (e.g., junior enlisted through junior leader; E1-E6/O1-O2/WO1-CW2).
Journeyman: A person who can perform a day's labor unsupervised, although according to orders. An experienced and reliable worker, or one who has achieved a level of competence. It is possible to remain at this proficiency level for life.	Established leader or management role; works independently to complete tasks and ensures others do as well. Competent and confident in familiar operational contexts (e.g., E5-E8/O3-O5/CW2-CW4).
Expert: The distinguished or brilliant journeyman, highly regarded by peers, whose judgments are uncommonly accurate and reliable, whose performance demonstrates skill with little apparent effort, who can deal effectively with certain types of rare or "tough" cases, and who has special skills or knowledge derived from extensive experience.	Senior leader, policy development, strategic oversight; viewed as a role model to others in the organization. Demonstrates finesse and skill in uncertain operational contexts, even under pressure. Has foresight and wisdom to make brilliant decisions (e.g., E8+/O5+/CW4+).

At any given time, the military is conducting a multitude of training operations for occupational specialties, skill badges, professional military education, and tactical/technical skills sustainment. Domain specific training encompasses a skill progression from acquiring knowledge to putting that knowledge into action and adapting it to face new challenges. With intention and experience those skills become second-nature, vested in the individual and made evident by performance improvements within and beyond the original domain. In most training environments the development of cognitive skills occurs as a natural byproduct of experience. Formal training is focused on acquiring what is necessary for the body to perform a given set of tasks. However, cognitive domain general skills are a significant component of domain expertise as well as the development of adaptive expertise.

The developmental phases described in Table 1 are defined largely in terms of performance outcomes; decreasing error and reliable success are indicators of increased expertise. Performance improvements may be sufficient evidence of reliable, successful task execution but not the creative, adaptive thinking the military needs to be most effective in modern conflict (e.g., U.S. Department of the Army Training and Doctrine Command, 2014). Adaptability represents an extension beyond most behavior-based proficiency scales; a continuum of Service Member adaptive expertise must also be able to capture cognitive development.

Cognitive scales of expertise development, such as the Cognitive Readiness Model (O'Neil, Perez, & Baker, 2014), outline the mental changes underlying observable performance outcomes. This model depicts three phases of growth (knowledge, skills, and attributes) required for developing cognitive readiness. Cognitive readiness is akin to expert-level proficiency and has been defined as "the mental preparation (including knowledge, skills, abilities, motivations, and personal dispositions) needed to establish and sustain competent performance in a complex and unpredictable environment" (Fletcher, 2004; O'Neil, Perez, & Baker, 2014, p.3).

O'Neil and colleagues (2014) identified a list of skills that comprise the concept of cognitive readiness and built a model that provides a means for measurement and training. The list of cognitive skills includes (in alphabetical order): adaptability, adaptive expertise, adaptive problem solving, communication, creative thinking, decision making, metacognition, situation awareness, and teamwork. Each of these concepts have specific definitions relevant to the development and measurement recommendations outlined in the model. It follows then that if psychological skills training is applied in a dynamic tactical training environment, previously unintentional outcomes – like adaptive expertise development – may be deliberately trained in Service Members using existing strategies and available resources. The challenge that remains for training designers is the effective integration of the domain specific and domain general cognitive skills with the physical skills required for the field.

Military training progression is consistent with behavioral and cognitive models; therefore, a general model of the development of adaptive expertise in the military must recognize and address both elements and explain the events and changes underlying progression from novice to adaptive expert. The proposed model integrates the Cognitive Readiness Model (Fletcher, 2004; O'Neil, Perez, & Baker, 2014), which involves mental changes underlying observable performance outcomes in a knowledge-skills-attributes framework. Knowledge is domain specific and independent; it refers to prerequisite information. Skills, also domain specific and independent, include adaptability, problem solving, decision making, and situational awareness. Attributes – creative thinking, metacognition, and teamwork – are domain independent.

Research demonstrates that performance enhancing changes in cognition, the mental process underlying learning, understanding, and performance outcomes, are facilitated by domain-general foundational skills that facilitate superior cognitive functioning and enhance the psychological abilities required for basic human learning (e.g., using imagery to rehearse evaluating a casualty). The defining feature of adaptive expertise – the ability to adapt existing knowledge to new situations – is predicated on metacognitive skill development and use (Eccles & Feltovich, 2008).

Military training currently values progression of performance in ways that are consistent with elements of these two models – behavioral and cognitive. Because Service Member expertise is a combination of cognitive and behavioral skills, a general model of the development of adaptive expertise in the Army must recognize and explain both of those elements. More importantly though, it must be able to explain the events and changes underlying progression to illustrate how Service Members develop from novices to adaptive experts.

It follows then, that metacognitive skills training represents an opportunity to catalyze the development of adaptive expertise while improving occupational performance outcomes as illustrated in the Comprehensive Proficiency Model (Figure 1). This model illustrates the potential of metacognitive skills. Domain general metacognitive skills can be intentionally integrated into existing training platforms. Following the initial acquisition of essential domain-general metacognitive skills, individuals can adapt the skills to their operational demands to develop specific competencies and abilities which facilitate improved performance outcomes.

Figure 1. Comprehensive Proficiency Model

TESTING THE COMPREHENSIVE PROFICIENCY MODEL: APPLIED COGNITIVE TASK ANALYSIS

Overview

Following model development, testing of the Comprehensive Proficiency Model began by using Applied Cognitive Task Analysis (ACTA) to identify requisite cognitive skills and describe their evolution across the expertise development of an Army occupational specialty. Task analysis refers to the observation and breaking down of a task into smaller steps and is frequently used in education to inform curriculum design or develop task protocols. ACTA is "the extension of traditional task analysis techniques to yield information about the knowledge, thought processes, and goal structures that underlie observable task performance" (Schraagen, et al., 2000, p.1). ACTA is used to capture the observable and underlying elements of performance and has been utilized successfully to design training in aviation, industrial, and military contexts (Clark & Estes, 1996; Crandall, et al., 2006).

ACTA is an umbrella term encompassing a range of methodologies, each designed for use in a particular setting or context. In a military setting, the 5-step streamlined CTA methodology developed by Militello and colleagues (1997) has been successfully utilized for breaking down complex tasks to inform training development (Table 2).

Table 2. Applied Cognitive Task Analysis (ACTA) Methodology

Step	Description
Bootstrapping	Researchers become familiar with the domain and task.
Task Diagram	Researchers deconstruct the identified task into 3 to 6 key steps, in collaboration with a subject matter expert (SME).
Observation	Researchers observe the key task *in vivo*.
Knowledge Audit	Following observations, researchers conduct interviews with SMEs and record the knowledge (domain and other) required for successful execution of the task.
Expertise Matrix	Researchers conduct interviews with SMEs and novices, recording the cognitive strategies used by each group during task execution.

This robust yet efficient and widely applicable methodology includes several elements key to comprehensively understanding and contextualizing training: a) familiarization with the identified task; b) considerations to minimize error; c) guidelines to create a shared, consistent language of cognitive skills between the research team and the SMEs; and d) tools to elicit both the knowledge structures required for the successful completion of the task and the cognitive skills that distinguish expert performance from that of a novice or other.

To test the Comprehensive Proficiency Model and determine the cognitive skills underlying the development of expertise, the research team conducted three trials of ACTA with three separate domains and tasks: 1) medics participating in an expert-level casualty care exercise; 2) flight paramedics participating in medical evacuation operations training; and 3) AH-64 Apache helicopter pilots participating in a helicopter gunnery exercise as a part of pre-deployment certification. Participants were Army National Guard Soldiers at Fort Hood, TX. Each trial utilized the 5-step ACTA methodology as well as focus group discussions for validating observations and enhancing the richness of collected data. Each setting revealed unique emphases and adaptations of cognitive skills. For the purpose of brevity, this paper presents excerpts from each step of the ACTA methodology for AH-64 Apache gunnery.

To better understand the responsibilities and complexities of these roles, the researchers identified cadre members with extensive experience (SMEs) and utilized their knowledge and experience through interviews and assistance in understanding observations. In the MEDEVAC task, each cadre member had experience as a ground medic (68W) for several years before obtaining the 68WF status and had since served during multiple deployments in that capacity. In the gunnery task, each cadre member had multiple successful gunnery experiences, was tracked as a Pilot in Command and/or a Master Gunner, and had completed multiple deployments in that capacity. Data collection consisted of observations during tape review and grading of Apache gunnery, as well as 9-line MEDEVAC initiation and pick up.

An ACTA Example: Apache Gunnery

As described in Table 2, the first task of ACTA was to gain familiarity with the environment and tasks associated with the selected population. Prior to conducting the site visit, the research team engaged in bootstrapping activities by reviewing program of instruction (POI) materials and mission-essential task lists (METLs). The first on-site task was to create a task diagram with the assistance of an identified SME. This was validated with other cadre members before moving on to observation. Figure 2 presents a task diagram of the gunnery task for AH-64 Apache pilots.

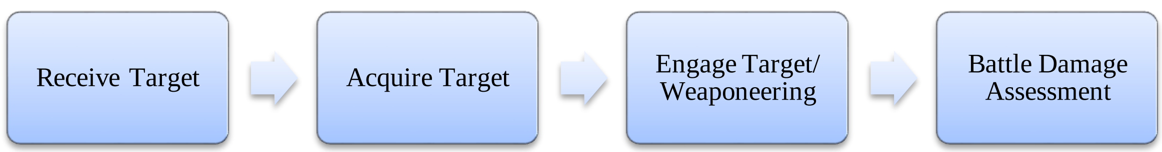

Figure 2. Task Diagram for AH-64 Apache Pilot Gunnery

Next, researchers observed the tape review and grading following a gunnery exercise and completed a knowledge audit with the assistance of the SME. During the knowledge audit, information was recorded regarding the aspects of expertise as they exist within the specific domain. The aspects of expertise included in the data collection process were derived from the ACTA Practitioner's Toolkit and augmented based on observations and assessment. Table 3 presents an excerpt from the knowledge audit.

Table 3. Selection from Knowledge Audit for AH-64 Apache Pilot Gunnery

Aspects of Expertise	Cues and Strategies of Expert	Why Difficult for Novice?
Tricks of the Trade (Example: Aim lower for shrapnel-based weapons.)	Considers weapons profile and impact. Places round(s) based on projectile path rather than 'bullseye.'	Seek to hit a 'bullseye' rather than aim based on the weapons profile; they do not adjust actions.

In Table 3, "Tricks of the Trade" is listed as an aspect of expertise, which refers to experience-based decisions and conceptualizations that experts have gained. The SME suggested that effective use of weapons based on their ballistic profile meets this criteria. An expert pilot is able to place the desired armament so that the target is neutralized without collateral damage or the need to re-engage. For example, weapons which deploy shrapnel are placed in front of rather than directly on the target. For a novice pilot who does not yet understand or perhaps is uncomfortable relying on their knowledge of ballistic profiles, the tendency is rather to aim for a "bullseye." This may result in an incomplete or unsuccessful neutralization of that target. The SME described this as "using a scalpel, not a hammer" to successfully engage targets. The output of the knowledge audit depicts clear distinctions between the knowledge, skills, and attributes of experts compared to novices. Connecting the technical task with metacognitive skills, expert pilots engage in imagery and, using their knowledge of their weapons systems and aiming skills, correctly place the desired round to obtain the desired result.

The final step in the ACTA methodology is to develop an expertise matrix (Table 4) with the assistance of the SME. The expertise matrix captured differences between the actions and cognitive skills between proficiency levels. Based on discussions with SMEs and previous related investigations, there was inconsistency between domains in the definition and application of proficiency labels; specifically, SMEs had difficulty delineating between some of the five proficiency levels (e.g., apprentice vs. journeyman). By reducing the matrix to three proficiency levels – novice, proficient, and expert – SMEs were able to clearly and reliably differentiate between the skills and behaviors of performers at each level.

Table 4. Selection from Expertise Matrix for AH-64 Apache Pilot Gunnery

Task	Novice	Proficient	Expert
Receive Target	Unsure of what to expect or how to prepare; radio drives action; behaviors are reactive.	Knows what the sequence of steps will be when a mission comes in; is prepared to receive; proactive and reactive.	Equipment set up to receive the mission in an intentional, personalized way based on past experience; controls inputs (radio prioritization); proactive and responsive.

During the Apache AH-64 gunnery observations, the SME noted the difference in behavior prior to receiving a target. As shown in Table 4, novice pilots' behaviors are driven by incoming information, reacting to information as it comes in rather than intentionally responding to information based on its prioritization. Proficient pilots predict based on past experience and understanding of the gunnery task what the order of events' information will be. These pilots are able to prioritize the incoming information and direct their attention as needed. In contrast, expert pilots prioritize and selectively attend to incoming radio communication, as it is worth noting there are five separate radios in the aircraft. Expert pilots are able to set conditions for success by attending to communication with a known priority (e.g., SATCOM radio relaying troops in contact with enemy fire) and responding to information with intention.

Another outcome of the ACTA was an approach to identifying domain general metacognitive skills that experts acquired over time and through experience, and tailored based upon their progression to expertise. For the AH-64 Apache pilots, findings indicated that prioritization and attention control are examples of trainable cognitive skills that correlate to differences between expert and novice performance (Figure 3).

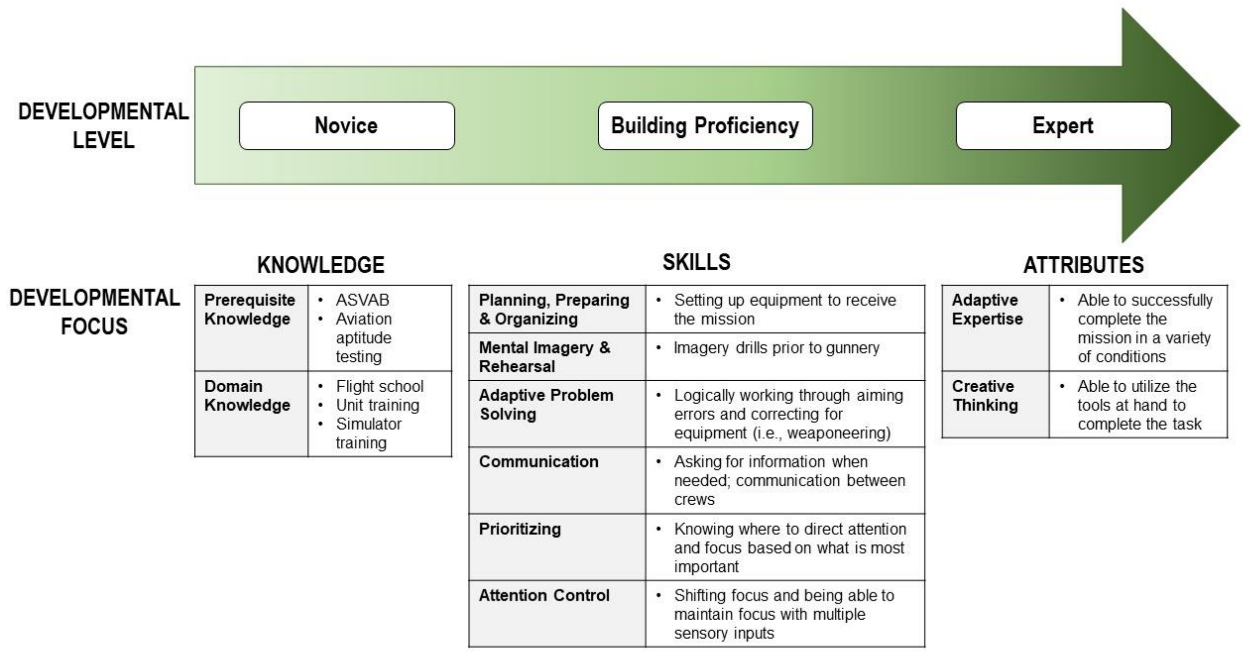

Figure 3. Metacognitive Skills and Adaptive Expertise Development Demonstrated in the Helicopter Gunnery Skills Test

SUMMARY

The ACTA methodology pinpointed requisite skills and demonstrated their evolution across the expertise continuum of three MOSs, with the sample depicted in this paper focused on AH-64 Apache helicopter pilots. ACTA is efficient, robust, and captures observable and underlying elements of performance; it has been applied in aviation and military training (Clark & Estes, 1996; Crandall, et al., 2006; Militello, et al., 1997; Schraagen, et al., 2000). ACTA tools elicit the knowledge structures required for successful task completion and the cognitive skills that distinguish expert performance from developmental phases on the continuum.

Beyond assessing the model's viability, including three domains and tasks allowed a means to identify best practices for implementing ACTA with a range of complex, technical tasks. The data from all three domains and tasks support the proposed comprehensive proficiency model, demonstrating the utility of metacognitive skills in military tasks and differences in skill usage by developmental level. Moreover, these data strengthen the rationale for integrating metacognitive skills training with military technical training to aid learners in deliberately acquiring the skills they need to become adaptive experts, and offering learners opportunities to practice using those skills in controlled environments where the potential consequences of trial and error are significantly less dire.

NEXT STEPS AND RECOMMENDATIONS

The ACTA trials support the utility of metacognitive skills in military tasks and demonstrated unique differences in their usage by developmental level. Follow-up discussions with SMEs confirmed that cognitive skills were not formally trained, nor were they included as a part of unit-based training. Rather, identified cognitive skills may be "picked up" over time and through experience. Experiential or error-based learning can be extremely valuable; however, error-based learning in many military domains incurs exceptional risk. A performance error in aviation or emergency medicine, for example, may have fatal consequences for the Service Member or for those impacted by his/her actions (e.g., patients, troops in contact).

For this reason, future training and education must include ways to provide Service Members the skills they need to develop adaptive expertise prior to actual combat operations. Informed by the Comprehensive Proficiency Model, the 5-step ACTA methodology (Militello, et al., 1997) described in this paper was sensitive enough to be able to capture the metacognitive skills required for development in vastly different military tasks (Figure 3) and demonstrated scalability through the effort to apply the methodology to three distinct MOSs.

Cognitive skills training programs exist within the U.S. military, but the degree to which they are integrated into institutional and unit training offers the greatest opportunity for targeted growth. Cognitive skills training has been empirically shown to offer meaningful impacts to technical and tactical performance (e.g., Adler, et al., 2015), but it is frequently offered alongside or separate from institutional or unit training and delivered nearly exclusively in person. As noted by the SMEs participating in the ACTA trial, even when a military service has a cognitive skills training program, the program may be unable to reach every Service Member in every unit. Cognitive skills training plans are typically developed by relying on the knowledge, skills, and abilities of expert cognitive trainers to understand the context and needs of the organization from an informal training needs assessment. Incorporating a formal and evidence-based stepwise process like ACTA would likely validate what the expert cognitive trainer identifies as relevant skills to improve task performance, but would add rigor and promote repeatability by clearly documenting which and how those domain general and domain specific skills are manifested in expert performers and how they relate to the METL.

These findings support the intentional integration of metacognitive skills training, first into existing institutional learning environments across occupational specialties to accelerate the acquisition of adaptive expertise and improve domain performance, followed by unit training environments. Applying the evidence-based method presented in this paper, military and civilian leaders can document the specific skills required for adaptive expert performance based on the desired performance outcomes presented in the METLs, which are a key component in shaping a modern and integrated institutional training strategy. ACTA artifacts, such as those produced by the research team (samples shown in Tables 2 through 4 and Figures 2 and 3), are ready to be incorporated into training analyses. Through this intentional integration, metacognitive skills training would become a full-fledged part of the technical training POI as opposed to an elective offering. The authors recommend beginning this effort in the institutional environment, where leaders can apply this process to ensure that every Service Member acquires the strategies and techniques needed to develop metacognitive skills, at targeted developmental points in the career cycle that are inclusive of, but not limited to the leader development pipeline. Additionally, ACTA artifacts provide a basis for the identification of objective assessment tools and methodologies to evaluate the effectiveness of the training and skill acquisition.

Future work to inform training should explore the metacognitive skills common amongst diverse tasks as well as those specific to respective branch operations. In doing so, baseline metacognitive skills may be integrated into initial entry training and later adapted to the Service Member's occupational specialty, evolving with the career cycle. An integrated, tiered metacognitive skills training program at both the institutional and unit levels represents a streamlined, intentional, non-disruptive potential solution to developing the adaptive experts needed to meet the demands of modern national defense.

Advances in immersive (e.g., virtual and mixed reality) and adaptive learning technologies should also be evaluated for their effectiveness in supporting domain general metacognitive skill development and addressing scalability challenges inherent in delivering standardized, quality training to broad communities of learners. These technologies should be considered as approaches to offering self-paced, customized, on-demand instruction, but also for their ability to provide engaging, adjustable skill practice opportunities and in-the-moment feedback. Developing a blended learning approach with guided, domain specific metacognitive skills instruction maybe an optimal methodology for developing an institution-wide adaptive expert community.

Finally, this paper should also serve as encouragement to leaders in domains beyond the military to consider how they are preparing their workforces to respond to the challenges of the digital age, as adaptive expertise is a relevant construct for every modern workplace. There is already a small but growing interest among researchers and educators in the engineering and healthcare career fields in applying the findings of this paper. The research team's successful implementations of ACTA with various technical specialties, coupled with the presented approach to identifying domain general skill applications alongside domain specific nuances, supports the broad applicability and relevance of the ACTA methodology as a component of training and education for our evolving digital world.

ACKNOWLEDGEMENTS

The authors would like to acknowledge and thank Andrea Ray, Elizabeth Brookhouse, Chang-Hyun Ko, and Drs. Denise Haselwood, Dave Brunner, Tyler Masters, and Les McFarling for their contributions to this project.

REFERENCES

Adler, A. B., Bliese, P. D., Pickering, M. A., Hammermeister, J., Williams, J., Harada, C., Csoka, L., Holliday, B., & Ohlson, C. (2015, May 25). Mental skills training with basic combat training soldiers: A group-randomized trial. *Journal of Applied Psychology, 100*(6), 1752-1764.

Chi, M. T. H. (2006). Two approaches to the study of experts' characteristics. In K. A. Ericsson, N. Charness, P. J. Feltovich,& R. R. Hoffman (Eds.), The Cambridge handbook of expertise and expert performance (pp. 21-30). Cambridge: Cambridge University Press.

Clark, R. E., & Estes, F. (1996). Cognitive task analysis for training. *International Journal of Educational Research, 25*(5), 403-417. DOI: 10.1016/S0883-0355(97)81235-9

Crandall, B., Klein, G., Klein, G. A., & Hoffman, R. R. (2006). Working minds: A practitioner's guide to cognitive task analysis. Cambridge, MA: MIT Press.

Croskerry, P. (2005). Diagnostic failure: A cognitive and affective approach. In: K. Henriksen, J. B. Battles, E. S. Marks et al., editors. Advances in Patient Safety: From Research to Implementation (Volume 2: Concepts and Methodology, pp. 241-252). Rockville, MD: Agency for Healthcare Research and Quality (US). Retrieved from: https://www.ncbi.nlm.nih.gov/books/NBK20487/

Dreyfus, S. E. & Dreyfus, H. L. (1980). A five-stage model of the acquisition of the mental activities involved in directed skill acquisition. AFSC: USAF (contract F49620-79-c-0063). Berkeley, CA: University of California.

Eccles, D. W., & Feltovich, P. J. (2008). Implications of domain-general "psychological support skills" for transfer of skill and acquisition of expertise. *Performance Improvement Quarterly, 21*, p. 43-60. DOI: 10.1002/piq.20014

Fisher, F. T., & Peterson, P. L. (2001). A tool to measure adaptive expertise in biomedical engineering students. ASEE Annual Conference Proceedings, 1249-1263. Retrieved from https://www.scholars.northwestern.edu/en/publications/a-tool-to-measure-adaptive-expertise-in-biomedical-engineering-st

Fletcher, J. D. (2004). Cognitive readiness: Preparing for the unexpected (No. IDA-D-3061). Alexandria, VA: Institute for Defense Analysis. Retrieved from https://www.researchgate.net/publication/235026215_Cognitive_Readiness_Preparing_for_the_Unexpected

Hoffman, R. R. (1998). How can expertise be defined? Implications of research from cognitive psychology. In R. Williams, W. Faulkner, & J. Fleck (Eds.), Exploring expertise (pp. 81–100). New York, NY: Macmillan.

Kalyuga, S. (2007). Expertise reversal effect and its implications for learner-tailored instruction. *Educational Psychology Review, 19*(4), 509-539. DOI: 10.1007/s10648-007-9054-3

Militello, L. G., Hutton, R. J., Pliske, R. M., Knight, B. J., & Klein, G. (1997). Applied cognitive task analysis (ACTA) methodology. San Diego, CA: Navy Personnel Research and Development Center. Retrieved from https://apps.dtic.mil/dtic/tr/fulltext/u2/a335225.pdf

O'Neil, H. F., Perez, R. S., & Baker, E. L. (2014). Teaching and measuring cognitive readiness. New York, NY: Springer.

Schraagen, J. M., Chipman, S. F., & Shalin, V. L. (Eds.). (2000). Cognitive task analysis. New York, NY: Psychology Press.

U.S. Department of the Army, Training Doctrine and Command. (2014). The US Army operating concept: Win in a complex world (PAM 525-3-1). Fort Eustis, VA: US. Department of the Army Headquarters, United States Army. Retrieved from https://apps.dtic.mil/dtic/tr/fulltext/u2/a611359.pdf

Wineburg, S. (1998). Reading Abraham Lincoln: An expert/expert study in the interpretation of historical texts. *Cognitive Science, 22*(3), 319-346. DOI:10.1207/s15516709cog2203_3