ACCELERATING LEARNING OF COMPETENCE AND INCREASING LONG-TERM LEARNING RETENTION

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Abstract

This paper explores techniques and strategies for accelerating learning, examining the expertise and cognitive psychology literature. However, it does little good to attain a higher level of competence quickly if it leads to poorer knowledge and skill retention. This paper explores retention of expertise and provides guidelines for better retention.

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14. ABSTRACT

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ACCELERATING LEARNING OF COMPETENCE AND
INCREASING LONG-TERM LEARNING RETENTION

Introduction

Accelerated Learning Defined

Training experts in The United States Department of Defense are exploring ways in which officers and enlisted personnel may be better and more quickly prepared to handle the complex tasks with which they are faced in the very dynamic environments of today's deployments. To address these training challenges, a recent research focus has been on accelerated learning. A US Department of Defense scientific advisory group defines accelerated learning as any learning system or environment that attempts to control for _time_ spent versus _content learned_ with the goals of: 1) faster attainment of skill and knowledge, and an increase in on the job performance with better retention of learning, and 2) quick assimilation and conversion to training content battlefield lessons learned.

Nature of the problem for the military

Current conflicts do not follow traditional wartime patterns. Officers and enlisted personnel are faced with missions that require the applications of skill sets that are relatively new to the force. Specifically, the engagements in which we are involved today are characterized by irregular warfare (IW) in a struggle between nations and non-state actors for influence over targeted populations. According to the US Department of Defense Irregular Warfare Joint Operating Concept (2007), "Our adversaries will pursue IW strategies, employing a hybrid of irregular, disruptive, traditional, and catastrophic capabilities to undermine and erode the influence and will of the United States and our strategic partners" (p. 1.). Thus, it is necessary for coalition partners to address the wide range of aspects that will assure the success of the mission. People are the key to ensuring that the political, cultural, social, and religious aspects of the mission are appropriately addressed.

Our forces are exceptionally well-trained in many complex cognitive skills, with IW issues adding further complexity to already challenging roles for the military. In IW, as well as in Counterinsurgency (COIN), and Stability, Security, Transition, and Reconstruction Operations (SSTRO), military personnel need to conduct dynamic, complex, and ill-defined tasks. For instance, skills in real-time situational understanding and in dynamically planning or re-planning are required in IW, COIN, and SSTRO missions to enhance the chances of success. Real-time situational understanding includes the ability to determine the military implications of fused intelligence indicators, all sources of information, and orders of battle, to name a few of the important aspects of the dynamic environment. To make matters more complex, considerations must be seen in Diplomatic, Informational, Military, and/or Economic (DIME) or Political, Military, Economic, Social, Infrastructure, and Information Systems (PMESSI) contexts. Similarly, in dynamic planning and re-planning, personnel need kinetic battle space skills in order to manage the battle space and prevent interference in coalition operations. They must also have non-kinetic skills as well. Specifically, personnel must have the ability to evaluate, assimilate, and act in both the physical and civil (political, cultural, and economic) environments of the battle space, leveraging non-military organizations. Finally, it is crucial to cultivate the interpersonal skills that are required for awareness and understanding of the societal and cultural factors when providing aid to a local population.

Another motivating reason for investigating the techniques and effectiveness of accelerated learning is that military personnel may also have problems retaining knowledge and skills during career broadening rotations. For many officers, career advancement requires a broad range of demonstrated skills and abilities, leading to a variety of assignments over the course of one's career. For example, a skilled pilot may be required to serve a three year rotation in a supervisory position in a ground facility. During this time period, flight skills are often not exercised, leading to the decay of those skills to varying degrees depending upon the level of competence and length of time away from flying.

Typically, the pilot undergoes recurrent training prior to rejoining the flight line, which may be time-intensive and costly following a long-term hiatus in a career-broadening position.

When training considerations are made, a number of factors need to be considered. Figure 1 shows the tradespace of the three elements of accelerated learning: time to train, the cost of training other than time, and the complexity of the content to be trained. Each of the elements has a correlation to the other two and tradeoffs are made in determining the timing and content of training events. In general, if we only have a short time and few resources for training, we can train only fairly simple content. One example is rudimentary map reading skills. Conversely, if the content to be learned is complex, we must allow considerable time, sometimes years, for the acquisition of that skill or knowledge, and we must spend considerable non-time resources. An example is becoming a journeyman in the sonar operations field.

Research in accelerated learning seeks to provide a way to train more complex skills more quickly while using fewer non-time resources. However, we may find in some cases that in order to train complex content in shorter time we must bring more non-time resources (e.g., instructors, computer-based training, tutors) to the equation. The figure shows generally that today, if we want to have someone learn the complex content required of many mid-career level warfighters, we must allow years and very significant investment of other training resources. On the other hand, due to the pressing need to train warfighters in irregular warfighting content quickly we can only train them to a fairly simple level. Finally, as the figure illustrates, competence may decay over time, requiring refresher training to bring the knowledge and/or skills back to par. This is crucial in a military context because of frequent redeployments that often result in rapid skill decay and expensive re-training (Hoffman, Feltovich, Fiore, Klein, & Andrews, 2009). Employing accelerated learning techniques has great potential in aiding our troops to quickly and effectively gain the competence required for their deployment or to retain the skills they have mastered while they are performing other duties.
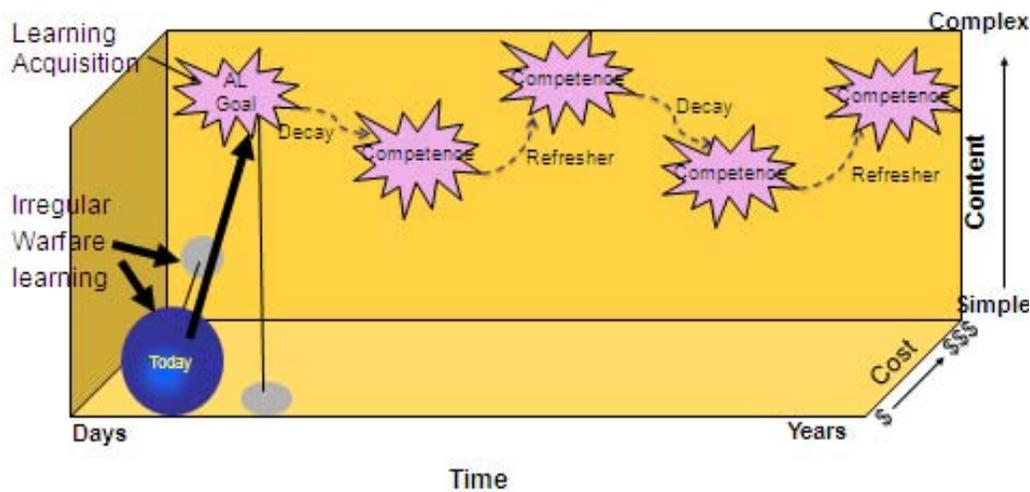

Figure 1. Accelerated Learning Tradespace

Foundations of accelerated learning

Competence and Expertise

Many definitions of competence may be found in the psychological and cognitive literature. For the purposes of this effort, we contend that competence is present at varying levels along a spectrum of experience (ab initio, novice, journeyman, and expert). When one enters a field, they are at the ab initio level with little competence in their domain. As experience and competence increase, the initiate moves through the novice and then the journeyman levels. When a high degree of competence has been attained, one can generally be considered and expert.

A number of characteristics differentiate experts from other performers. Hoffman (1996) asserts that expertise can be defined by three specific dimensions: its development, the knowledge structures of the experts, and their reasoning processes.

The development of expertise cannot be attributed to maturation alone; experience and repeated deliberate practice are essential to reaching expert levels in a field (Hoffman, 1996). Although some assert that expert performance can be noted after approximately 10 years, it is not uncommon for a recognized expert to have been in a field for 20 or even 30 years. The primary factor often depends upon the extent to which the performer is engaged in relevant and diverse tasks. If the skills are not expanded in complexity, time spent conducting basic tasks will not lead to expertise.

In terms of knowledge structures, the literature supports the idea that experts possess a wide array of concepts and patterns of the information they have accumulated about their field (Schumacher & Czerwinski, 1992). Expert knowledge structures are abstract, whereas the knowledge structures of novices are comprised of surface features of the learned material. The ability to form more abstract representations allows experts to interrelate pieces of information that would be missed by novices, facilitating access to deeper structures of the domain along with a greater understanding of relevant relationships.

Experts' bodies of knowledge include many abstractions that are interrelated and organized, providing experts with novel information representations that are available for access. Moreover, the reasoning processes employed by experts differ from those of novices (Hoffman, 1996). Because of their sophisticated knowledge structures, experts are better able to anticipate problems and find appropriate solutions in a more efficient manner, learning from errors when they do occur (Groen & Patel, 1988). Furthermore, experts are better able to attend to important information, ignoring factors that are not relevant. Finally, it is widely observed that experts often have difficulty articulating how they conduct the work in which they have gained expertise.

Learning Retention

In their meta-analysis of retention studies, Arthur, Bennett, Stanush, & McNelly (1998) identified the factors associated with skill decay. The retention interval, or the period of time in which the skill is not used, is inversely related to retention. That is, the longer the retention interval, the less retention of the skill is evidenced. In fact, after one year, performance fell by 92%. Although the extent of the loss of skills is likely not this great, such a drastic drop in performance strongly suggests some degree of skill decal.

Natural, physical, and speed-based tasks do not evidence as much skill decal as cognitive, accuracy, or artificial tasks. Many of the past studies of over-learning suggest that over-learning moderates skill decay. The meta-analysis offers some support for this contention; however, a small number of data points are a limiting factor. Lastly, the similarity of the training task to the actual environment effects retention. Transfer and retention of competence is more likely the more closely the two environments are matched.

There are a number of limitations associated with retention studies. One problem with most of the studies on retention to date is that they assess retention over short retention intervals. This is likely due to the fact that long-term retention studies are difficult to execute. It is difficult, if not impossible, to control for practice during the retention interval. Researchers cannot expect that a participant will refrain from engaging in their work for the benefit of experimental investigations. Furthermore, participants may not be able to return to participate in an experiment over long periods of time due to relocation, assignment to a new position, or any number of other factors. An additional challenge is that a majority of the studies are conducted in laboratory settings rather than in natural settings, raising questions concerning the extent to which the findings generalize to real-world settings.

Accelerated Learning

Goals of accelerated learning

The base of knowledge from the studies of expertise and knowledge/skill retention suggests the need for research on accelerated learning to identify the best practices in terms of the development and retention of competence. Accordingly, a set of goals for accelerated learning has been developed. One of the primary (and most obvious) goals associated with accelerated learning is to speed up knowledge acquisition in ways that are not detrimental to learning. Deeper learning and the development of robust knowledge and skill bases are additional goals that promote a higher level of expertise in the learner and likely a better retention of what is learned. Another key aspect of competent performance, and one in which accelerated learning may play a useful role, is the ability to appropriately generalize what has been learned to similar situations. Finally, accelerated learning applies across the learning spectrum, from novice to expert, and could play a crucial role in retaining hard-earned skills and knowledge.

Accelerated Learning Principles

Although routine practice is widely believed to contribute to the development of expertise, it is not sufficient for acceleration of competence. To effectively define an effective program for accelerating learning, the principles that form the foundation of that program must be identified. Accordingly, the learning R&D community articulates several principles that are known thus far. These principles can be instantiated in accelerated learning methods and technologies.
First, the learning program must address a constant "stretching" of the skill, defined by increasing challenges (i.e., tough or rare cases). Although practice is not sufficient to accelerate learning, it is necessary. Specifically, practice that provides rich, meaningful feedback aids in the development of complex knowledge structures that can be generalized to similar situations. Practice should also be based on mentoring, providing a wider range of experience. The learner plays a role as well. High levels of intrinsic motivation to work on hard problems are a necessary ingredient for successful acceleration of learning. Finally, provisions for individualized/tailored practice must be made due to the unique learning styles of each learner. To help in the individualization and tailoring process, training developers should use tools to help identify ripe targets for deliberate practice, tools that would be used by individual learners or the instructional systems/simulations they are using, and identify ways to design and match learning opportunities (instruction/simulations) with specific requirements for deliberate practice.

Because this is not an exhaustive list of accelerated learning principles, further investment is required to produce more principles especially aimed at complex tasks that must be rapidly learned for IW and/or for mid-career tasks.

Accelerated Learning Methods and Techniques

As discussed earlier, the DoD scientific advisory group on accelerated learning has thus far produced important principles for developing competence. Some of the factors associated with competent

performers, along with some training guidelines are displayed in Table 1. These factors were not developed with IW or mid-career learning specifically as a goal. The research question for accelerated learning in IW and mid-career learning is how well these principles will apply, and under what contingencies?

Competence Factors	Guidelines
Competent performers know a lot. Their knowledge is highly contextual.	Training must provide increasingly detailed knowledge, procedures, and principles, in context, with progressive refinement as expertise develops.
Competent performers' knowledge is structured.	Provide suitable knowledge structures early in training.
Competent performer's knowledge / skills are compiled and proceduralized.	Provide sufficient practice for experience to be compiled.
Competent performers tend to work forward from underlying principles rather than backward from the end goal.	Provide underlying principles as part of the knowledge structures. Provide unstructured end-goal exercises only after principles have been learned.
Competent performers examine a broad range of alternatives rather than explore a single alternative deeply.	Practice environment must provide for many alternatives and must model them correctly.
Competence keeps developing even after many years and thousands of opportunities for practice.	Provide journeyman-expert practice environments through simulation and carefully designed exercises.

Table 1. Competence factors and learning guidelines. (Personal Communication, Wulfeck, 2008)

In his presentation at The Air Force Research Laboratory's Accelerated Learning Workshop Goldstone (2008) discussed a number of specific techniques that may be employed to accelerate learning on complex tasks, especially ones in which cognitive tasks (e.g., decision making, problem solving) are involved. In general, optimal spacing of materials to be learned may be effective. Spaced practice is better than massed practice in learning complex skills (Kornell & Bjork, 2008; Rohrer & Taylor, 2006). Furthermore, the training curriculum should present enough repetitions so that material is mastered. However, overtraining without optimal repetitions is an inefficient use of time (Rohrer & Taylor, 2006). Optimal spacing depends upon the length of time the material should be retained, with an optimal intersession interval of 10-20% of the retention interval (Rohrer & Pashler, 2007).

According to Goldstone (2008), other researchers indicate that, in addition to assessment, tests are useful to improve learning. McDaniel, Roediger, & McDermott (2007) discuss the advantages of study-test over study-study. That is, taking an initial test soon after studying the material enhances learning and maximizes retention of the learned material, especially when corrective feedback is offered. Similarly, Lajoie (2003) advocates dynamic assessment during the learning process, stating that immediate feedback and assistance while solving a problem enhances learning. Active retrieval is another factor that is related to effective learning (Karpicke & Roediger, 2008). In their research studies, students receiving repeated tests after study recalled more information than their counterparts engaging in multiple study sessions.

Another technique includes using self-explanation (i.e., the self-directed building of knowledge over the course of the learning) in learning protocols (Chi, 2000). A significant result of using self-explanation is that one's mental model is updated and enhanced throughout the learning/self-explanation process. In contrast, others state that social factors, such as directed comparison, promote learning, especially in terms of revealing deep principles (Gentner & Namy, 2004; Loewenstein, Thompson, & Gentner, 1999; Rittle-Johnson & Star, 2007). Multiple studies support the idea that comparing performance to that of a peer facilitates the more success in learning and greater abstraction of the learned material.

According to Goldstone (2008) the use of technological solutions in the acquisition of competence is effective. Cognitive Tutoring Systems provide scaffolding, retrieval, practice, adaptive feedback as well as a learning lab for in vivo experimentation. Finally, emerging research indicates that learning is facilitated through the use of serious games, offering more time on the task, motivation, and engagement. Examples of serious games include: Immune attack, America's Army: Special Forces, Spore, and River City.

If used during the acquisition of competence, the above methods and techniques will contribute to the retention of competence during periods when expert skills are not exercised. However, during the period in which the expert is performing a different role, continued practice in some form will help to retain competency (Hoffman, et al., 2009). For example, a pilot can retain flying skills by flying difficult scenarios in a simulator while assigned to a different career broadening position.

Paradoxes of Accelerating Learning

Accelerated learning has clear positive implications, but it is imperative to consider some of the perils that may be encountered. Paradoxically, accelerated learning can be counter-productive. Speeding up learning without paying attention to the other training factors discussed in this paper may negatively impact retention of the learned material. Research is needed to determine where the sweet spot is in terms of the speed of learning versus the depth of learning. Additionally, accelerating learning in one area may have negative consequences in terms of generalizing the learned information to a different situation. Finally, shorter or faster training may result in a lack of readiness for task performance (i.e. one may meet the criteria to be deemed "ready", but longer training time may enhance retention).

Conclusions

While our understanding of accelerated learning and the methods and techniques required to successfully advance the science is growing, much work remains to be done. Research to investigate additional methods of accelerating the attainment of competence is required, with a particular focus on military domains. Additional work is required to identify ways in which competence can be maintained during career broadening assignments. To gain a greater understanding and improve training during these periods, longitudinal and long-term retention studies are needed. However, policy issues around funding for long-term projects is harder to solve than the methodological issues scientists confront in conducting such challenging research. Policy-makers often do not approve funding over long periods of time due to budget constraints. In one of the few cases known for this type of research, Project A was awarded a long-term budget to collect personnel data across the US services. They successfully saw the project to the end, but budget cuts were real possibilities throughout the effort. A long-term project would be the best way to address the retention questions and create training programs to accelerate learning and retention. Addressing these training requirements is crucial given the increasing complexity and the strain our military forces are currently facing.

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London, UK
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AF**RL**
THE AIR FORCE RESEARCH LABORATORY
LEAD I DISCOVER I DEVELOP I DELIVER

Definition of Accelerated Learning

What is "accelerated learning" ?

Any learning system or environment that attempts to control for _time_ spent versus _content learned_ with the following goals:

- Faster attainment of skill and knowledge, and increase in on the job performance with better retention of learning
- Quickly assimilate and convert to training content battlefield lessons learned

Current Warfighters are required to perform tasks for which they may not be well trained, when time is of the essence.

Examples of difficult tasks that must be quickly mastered in:
Irregular Warfare (IW),
Counterinsurgency (COIN), and
Stability, Security, Transition, Reconstruction Operations (SSTRO)

- **Real-time situational understanding**
  - Determine the military implications of fused intelligence indicators, all source information, orders of battle in the context of Diplomatic, Informational, Military, and/or Economic (DIME) / Political, Military, Economic, Social, Infrastructure and Information Systems (PMESII)
    - Develop options in Air Operations Centers in context of "whole-of-government" engagement

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Examples of difficult tasks (continued)

- **Dynamic planning/replanning**
  - Kinetic battlespace skills
    - Maritime battlespace management and the prevention of mutual interference in coalition ops
  - Non-kinetic knowledge development and analytic skills
    - In real-time Brigade ops planning -- evaluate, assimilate, and act in both the physical and civil (political, cultural, and economic) environments of the battle space leveraging non-military organizations

- **Interpersonal skills (the cultural chameleon)**
  - Achieving and making use of societal and cultural awareness
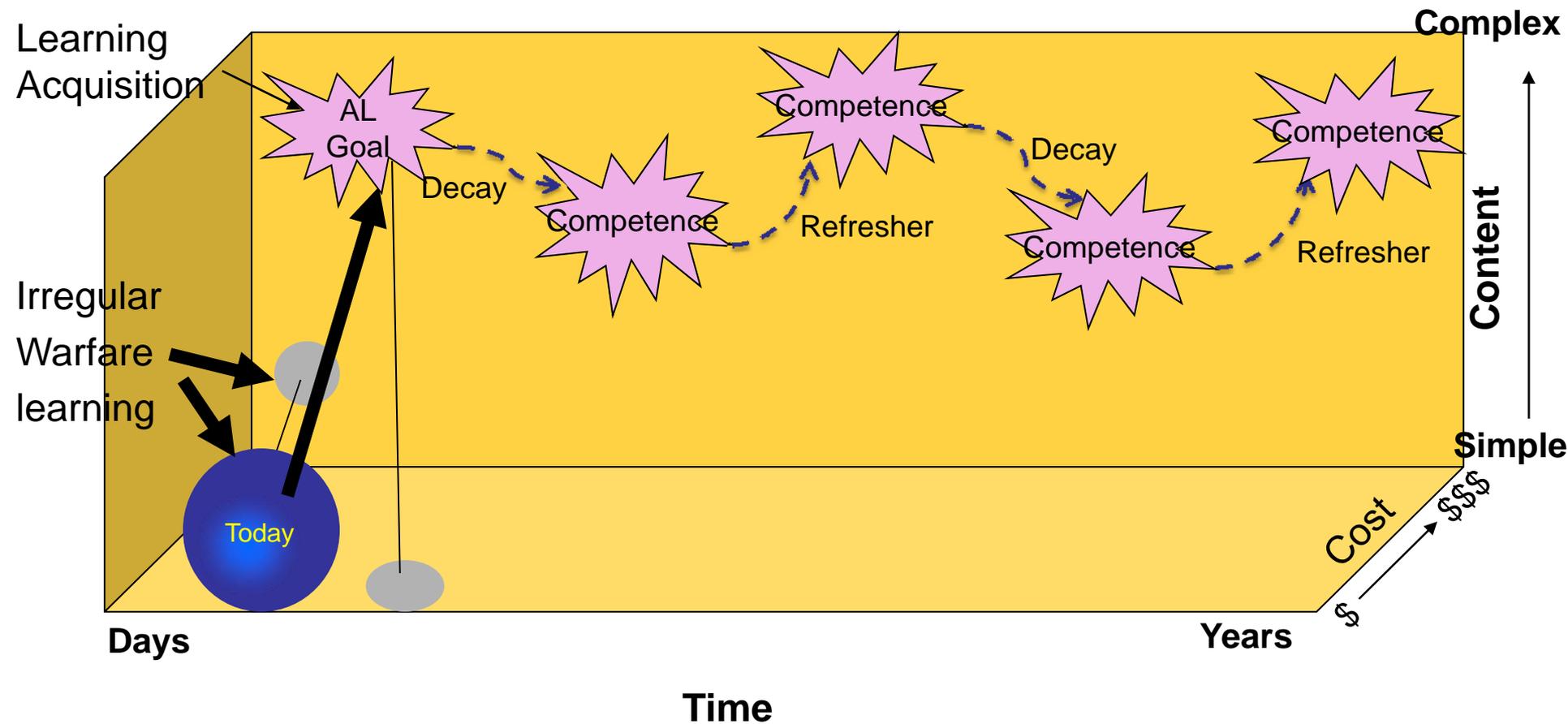
Nature of Expertise

- **Experts have engaged in repeated, deliberate practice over long periods of time**

- **Experts approach problems by their deeper, abstract structures (versus novice's focus on surface structures)**

- **Expert knowledge is represented and indexed in memory in multiple ways, and is readily retrieved in a given situation, leading to better anticipation of appropriate solutions**

(Hoffman, 1996;Hoffman, Feltovich, Fiore, Klein, & Andrews, 2009)

- **Factors that effect retention of complex skills**

  (Arthur, Bennett, Stanush, & McNelly, 1998)

  - **Retention interval**
  - **Task characteristics**
  - **Degree of overlearning**
  - **Instructional strategies/training methods**

Retention Studies

- **Factors that facilitate retention during acquisition**
  (Hoffman, Feltovich, Fiore, Klein, & Andrews, 2009)
  - **Deeply learned**
  - **Embellished**
  - **Connected to and integrated with other knowledge**
  - **Active learning (e.g., extrapolating, discussing)**

Retention Studies

- **Limitations of retention studies**
  - **Most studies involve simple tasks in a laboratory and have limited retention intervals**
  - **Longer retention intervals may be confounded because researchers cannot prevent participants from engaging in the task outside the research setting**
  - **Conducting studies over long retention intervals are often not practical in terms of participant dropout**

Goals of Accelerated Learning

- **Speed knowledge acquisition and retention**
- **Cultivate deeper learning and expertise**
- **Foster the acquisition of a robust knowledge/skill base**
- **Facilitate generalizability to similar tasks**
- **Retention of complex skills**

Accelerated Learning Principles

Routine practice is not enough for acceleration of competence. There needs to be:

- A constant "stretching" of skill, defined by increasing challenges (tough or rare cases)
- High levels of intrinsic motivation to work on hard problems
- Practice that provides rich, meaningful feedback
- Practice based on mentoring
- Provisions for individualized/tailored practice due to the unique learning styles of each learner

Sample Training Guidelines for Developing Competence

Competent performers know a lot. **Their knowledge is highly contextual.**	Training must provide increasingly detailed knowledge, procedures, principles, in context, with progressive refinement as expertise develops.
Competent performers' knowledge is structured.	Provide suitable knowledge structures early in training.
Competent performers knowledge / skill is compiled and proceduralized.	Provide sufficient practice for experience to be compiled.
Competent performers tend to work forward from underlying principles rather than backward from the end goal.	Provide underlying principles as part of the knowledge structures. Provide unstructured end-goal exercises only after principles have been learned.
Competent performers examine a broad range of alternatives rather than explore a single alternative deeply.	Practice environment must provide for many alternatives and must model them correctly.
Competence keeps developing even after many years and thousands of opportunities for practice.	Provide journeyman-expert practice environments through simulation and carefully designed exercises.

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Accelerated Learning Techniques

- **Optimal spacing of materials**
  - **Spaced is better than massed practice**
    (Kornell & Bjork, 2008; Dempster, 1989; Melton, 1970; Rohrer & Taylor, 2006)
  - **Optimal spacing: present enough repetitions to master material; overtraining is an inefficient use of time**
  - **Optimal spacing depends on how long material should be retained – optimal ISI interval = 10-20% RI interval**
    (Rohrer & Pashler, 2007)

- **Using tests to improve learning, not just assessment**
  - **Advantage of study-test over study-study**
    (McDaniel, Roediger, & McDermott, 2007)
  - **The importance of active retrieval for learning**
    (Karpicke & Roediger, 2008)

- **The benefits of self-explanation** **(Chi, 1996, 2000)**

R. Goldstone, 2008

Accelerated Learning Techniques

- **Directed comparison for revealing deep principles**
  (Gentner & Namy, 2004; Loewenstein, Thompson, & Gentner, 1999; Rittle-Johnson & Star, 2007)

- **Cognitive Tutoring Systems** (Anderson, Koedinger, Aleven, CMU)
  - **Principles: scaffolding, retrieval practice, adaptive feedback**
  - **Learnlab for in vivo experimentation**

- **Serious Games** (Barab, Castranova, Dede, Gee, Jenkins, Sawyer)
  - **"Immune attack", "America's Army: Special Forces," "Spore", "River city"**
  - **Time on task, engagement, motivation**

R. Goldstone, 2008

Paradoxes

- **Accelerating learning *may* have negative effects on retention of what was learned. The sweet spot must be found**

- **Accelerating learning in one area *may* have negative consequences in terms of generalizability to a different situation**

- **Shorter/faster training *may* result in a lack of readiness for task performance**

Conclusions

- **Additional methods of accelerating the attainment of competence is required, with a particular focus on military domains**

- **To gain a greater understanding and improve training during these periods, longitudinal and long-term retention studies are needed**

- **Policy issue is harder than methodological issues**
  - **Difficult to obtain funding for a long-term (10-year) program**
  - **Project A was an exception**
    - **Long-term cross service program to collect personnel data**
    - **Faced period threats of budget cuts**

Questions?

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