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MASTER OF MILITARY STUDIES

Title:
Building Potential for Pilot Expertise:
Can Understanding How People Think and Make Decisions Improve the Ability of
Military Flight Training to Create Potential Pilot Expertise?

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF MILITARY STUDIES

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Executive Summary

Title: Building Potential for Pilot Expertise: Can Understanding How People Think and Make Decisions Improve the Ability of Military Flight Training to Create Potential Pilot Expertise?

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Thesis: Based on current understanding of the naturalistic decision making process, Navy flight schools can improve the flight training program and increase the opportunity to create and train future expert pilots.

Discussion: Naturalistic decision-making is the study of how people use their experience to make decisions in field settings. Understanding that this is actually how people think and make decisions is at the root of how to teach them to improve this skill.

The flight-training program is designed to teach basic tactics, techniques, and procedures so that an inexperienced pilot can safely operate a complex aircraft. At the completion of flight training the new pilot has enough basic knowledge and skill that he can safely perform the basic maneuvers in the aircraft. The expectation is that this level of training is good enough until these new pilots can build up enough experience to become expert pilots, a process requiring many hours.

Flight school is, therefore, a safety stopgap that enables the truly inexperienced student to learn just enough to live to possibly become an expert. The problem with training merely competent pilots is that this goal stops well short of what is truly needed. The Navy needs expert pilots who can react quickly and intuitively in complex situations to execute sound judgment. Producing expert pilots should be the true end goal of the flight-training program. This goal is not reached nor sought during flight training but instead may occur years later after the novice pilots have built up enough experience.

Conclusion: By understanding how experts make decisions, through the use of a technique known as Cognitive Task Analysis (CTA), and focusing training efforts on building experience through the lens of expertise, Naval flight training can improve the pattern-recognition and intuitive decision-making capability of novice pilots and potentially bridge the gap between flight training and expertise.

“The secret to being a good pilot is good judgment . . .
the art of teaching judgment to a pilot is a secret.”
~ Dr. Fritz H. Brecke¹

Preface: A Pump, Not a Filter

In the summer of 2010, when I left flight school for the 3rd time, I was transitioning to my first non-flying tour and realized that I had spent almost ten years flying and over half that time was spent in flight training in one capacity or another. I began my naval aviation career with no flight experience and went through the standard process to become a pilot. Later, when the helicopter I flew was retired, I reentered flight school as an experienced junior pilot transitioning to a new aircraft. After another short operational tour, I returned to flight school, this time, as an instructor.

Throughout all my learning and teaching experiences, I was continually frustrated by the ineffectiveness and inefficiencies within the program. As an inexperienced student, I spent most of my time studying and memorizing the complex engineering of the aircraft. I also spent time memorizing procedures, but the ability to perform those procedures safely was only addressed during the instructional flights. Later, as a more experienced junior pilot transitioning to a new aircraft, references to the previous aircraft became “dirty words” to the instructor pilots. They didn’t know anything about the other aircraft and didn’t want to hear about how things used to be done. When I finally returned as an instructor, I quickly realized that many instructors were extremely skilled at operating the aircraft, but they were ignorant of the specific actions they took to perform at that level. Intuitively, they knew how to fly and did so well, but they had trouble explaining what they did. I spent the next three years trying to break down each maneuver to try to determine the best way to explain it to inexperienced students. I tried

to determine what the other instructors and I were doing differently than an inexperienced pilot, what we were looking at differently and what we were thinking about differently. My hope was that I could find more efficient ways to teach the basic maneuvers to help students understand them more quickly instead of just repeating the maneuver enough times that the student eventually figured out how to do it on their own.

My efforts to teach students to fly prompted me to think about what we were teaching them. We were teaching the basic tactics, techniques, and procedures to help them learn to operate an aircraft safely at the most basic level. As instructors, we might question a student's judgment and whether he would have a successful career in the Navy, but we were in the business of producing pilots with only a very basic set of skills, not evaluating or teaching their higher level functioning and decision making ability. This concept led to a fellow instructor jokingly reminding us that flight school is "a pump, not a filter." Sometimes we would even call someone we knew at an operational squadron to warn them about an individual student heading their way after we had signed off on his certification. We were so concerned about their ability to function and make sound decisions that we wanted to warn our friends of the risks we saw, but we did not feel that we had grounds to remove them from aviation. We passed them on and left them for others to deal with at a level when their judgment would actually be a criterion for evaluation. Our job was to train them in the basics not evaluate their higher level functioning. This mindset always perturbed me. Why were we not using the more experienced aviators filling instructor billets to provide insight? What was the real goal of flight school and were we achieving that goal?

My belief is that the structure of flight school has been designed to teach the basics required to keep new aviators alive long enough for them to build the experience, in the Fleet, necessary to become effective military pilots. By reducing the requirements to such an extreme, we make the new pilots nothing more than human autopilots. We fail to address the need for sound judgment in the fast paced and dynamic world of naval aviation. We should be training air warriors not autopilots and advancement in the understanding of the human mind and the decision making process, especially the realm of intuition, will provide potential methods to advance the flight training.

The Current Frame of Reference: The Way Things Are

In order to recognize the need for change, a brief summary of the current flight school system is necessary. This summary will focus on the relevant issues for discussion, such as how students are taught and the types of material covered, rather than details of the procedures and policies beyond the scope of this discussion.

Naval flight training consists of a series of phases. The first three phases, introductory, intermediate, and advanced, are typically known as “flight school”. At the completion of advanced training, the student has completed an introductory course in a helicopter, multi-engine airplane, or a jet. At the completion of this phase, the student earns his wings, the military designation qualifying him as a pilot instead of a student pilot. While the former students may be designated pilots, they are still learning. From the advanced course, the new aviators move on to a fleet replacement squadron (FRS). The FRS is where the new aviators are first introduced to a military aircraft and taught rudimentary tactics.

The standard flow of events within any phase is a series of classes, known as a ground school, followed by a series of events in a military simulator and then a period of flight instruction in an actual aircraft. The flow is repeated for each separate mission or tactical category. The ground schools typically consist of an instructor-guided review of material learned initially through self-study. The instructor teaches the class using a computer aided lesson plan, and the class concludes with a written exam. Classes are taught on tactics, techniques, and procedures as well as the engineering components on all the aircraft systems. Most of the engineering classes last two hours, but the tactics classes typically consist of multiple lessons and last two days. The simulator and flight

events each consist of an event brief followed by the event itself. The briefs for the simulator typically last thirty minutes and set up what will be covered with the simulator. The simulator teaches procedures and techniques utilizing real aircraft controls without the risk of mistakes of an actual flight. The flight events consist of a brief lasting two to three hours followed by a flight with an instructor. The brief is effectively an oral exam covering one of the aircraft systems as well as some tactics, techniques, and procedures relevant to the flight.

Each flight has a list of maneuvers to be performed on the flight. Each maneuver is designated as “demonstrate, introduce, or review.” “Demonstrate” means that the instructor performs the maneuver while the student observes. “Introduce” means that the student performs the maneuver with coaching from the instructor. “Review” means that the student is expected to perform the maneuver and is graded on his ability to perform. When the student completes the prescribed training syllabus, he leaves the FRS as a pilot qualified in model (PQM). This designation means that the pilot can safely perform the basic maneuvers of that model of aircraft. This designation represents the student’s departure from the formal training commands, but his training is still not complete.

To utilize the helicopter community as an example, the PQM has additional qualifications to earn. The next step is to be designated as a helicopter second pilot (H2P) indicating enough experience and proficiency to be a competent copilot during operational missions. The next designation is as a helicopter aircraft commander (HAC). A HAC is a helicopter pilot qualified to fly with and train PQMs and H2Ps. The HAC is the pilot in command during missions. Some missions do require additional training and designations, but the HAC is the first level where a pilot is authorized to take the aircraft

out on his or her own and is responsible for the safe completion of the mission as well as the lives of the crew. The top aircraft commanders within a squadron are usually chosen to return to the FRS or to one of the earlier stages of flight school to become instructors.

Introduction: Thinking about Thinking

The flight-training program reviewed above is designed to teach basic tactics, techniques, and procedures so that an inexperienced pilot can safely operate a complex aircraft. There are very sound reasons for this program to exist, and there will probably be some reluctance to change a program that has actually demonstrated a reduction in aviation mishaps, so the question becomes why change anything?

If the end goal of flight school is simply a pilot that is safe to perform basic maneuvers with no judgment required, then there is no reason to change, but I do not believe this to be the case. At the completion of flight training the new pilot has enough basic knowledge and skill that he can safely perform the basic maneuvers in the aircraft. The expectation is that this level of training is good enough until these new pilots can build up enough experience to become expert pilots, a process requiring many hours. Flight school is, therefore, a safety stopgap that enables the truly inexperienced student to learn just enough to live to possibly become an expert. The problem with training merely competent pilots is that this goal stops well short of what is truly needed. The Navy does not need competent pilots. The Navy needs expert pilots who can react quickly and intuitively in complex situations to execute sound judgment. Producing expert pilots should be the true end goal of the flight-training program. This goal is not reached nor sought during flight training but instead may occur years later after the novice pilots have

built up enough experience. Based on current understanding of the naturalistic decision making process, Navy flight schools can improve the flight training program and increase the opportunity to create and train future expert pilots. The primary expectation is that a shift in training methodology will bridge the gap between the end of traditional flight school and when a pilot becomes an expert.

Research (or the Lack Thereof)

Although research has been done on ways to utilize simulators more effectively in flight training, there is no indication of research utilizing modern understanding of how people think to determine more effective means of training. This paper tries to bridge the theoretical gap that exists between the current understanding of how people think and make decisions and the practical implementation of tools to improve training techniques. Some of these tools include Cognitive Task Analysis (CTA) and a video game called Space Fortress. There may be more and better tools available, but these are examples of some of the ways to apply the theory of how people think, learn, and decide to modern flight training. The theory behind CTA is that training people how to think is much better than teaching them what to think.

This study uses examples; most come from the research that created the theories described and are, therefore, not specific to aviation. Where applicable and available, I have tried to include personal experiences and examples specific to aviation to illustrate how the theory can apply. Ultimately the Navy can synthesize various complex theories into a cohesive whole that can be applied to improve military flight training.

Creating Expertise: Nature versus Nurture

An expert must meet three criteria. First, an expert's performance is consistently superior to that of his peers. Second, expertise produces concrete results. Third, true expertise can be measured and replicated, such as in a lab setting.² Appendix A contains a more thorough discussion of the many advantages of expertise. In 1985 Professor Benjamin Bloom published his book, *Developing Talent in Young People*, and examined the evolution of talent in individuals. He discovered that there were no innate indicators of future success, with the exception of height and body size in fields where physicality matters, such as sports. Instead, he discovered that there were three things that determined superior performance. The three indicators were intense practice, study with a dedicated teacher, and an enthusiastic and supportive family. Measurable intelligence seems to play little role in future success, and the most important of these three indicators was the amount and quality of the practice. "Consistently and overwhelmingly, the evidence showed that *experts are always made, not born.*"³ The implications of this simple finding are profound. If the key to expertise lies in the hands of the individual and does not rely on fate or genetics, then expertise can be taught. This is not to imply that creating experts is easy; the experience necessary still takes years of dedicated effort, usually around ten years or 10,000 hours of experience, but it does not rely on chance. The current flight school system expects novice pilots to gain the "right" experience through some form of osmosis from those with more experience. Flight training fails to ensure that the desired experiences are created.

Each operational squadron creates a syllabus through which novice pilots progress and qualify as aircraft commanders. These syllabi typically consist of a number of

mission areas that the novice must experience and get a grade card signed off by an aircraft commander. The cards specify what missions are required as well as some specific areas that must be addressed. Procedures must be tested, but the training commands consider the specific thought process of the more experienced pilot as just a technique and advisory only. To give a personal anecdote, while deployed with my second helicopter, I was training my second pilots on daytime search and rescue (SAR) techniques. My copilot thought he knew everything he needed to know about SAR because he'd learned all the procedures during training. After I had put him through his paces, he was finally able to rescue the simulated survivor. After he took a big sigh of relief, I asked him what we were going to do next. He replied that we were going to take the survivor back to the ship for medical treatment. That's when he realized he didn't know where the ship was anymore. He'd lost sight of it while he was working on the SAR and the ship had decided to turn off its navigational aid while we were away. He was operating in the middle of the ocean with no land in sight and no idea how to get the aircraft back to safety. I was able to use his mistakes to highlight how I had thought about the problem and what I'd done to maintain situational awareness of the ship's location as well as the nearest safe point of land. What I taught my copilot were my techniques for that scenario, but there is no standardization to ensure that the next aircraft commander would challenge him to explain his thought process. The requirement is only that the novice pilots are exposed to different missions and procedures. The assumption is that they will figure out how to think about these situations.

Deliberate Practice

Practice is the most valuable variable in terms of creating expertise as well as the most controllable aspect. The term practice can be confusing, as it implies that any time spent working on a subject eventually grants expertise, but this is not the case. Not all practice makes perfect, and most people practice by working on things they already know how to do. Practice alone is not enough; it must be a specific type of practice. K. Anders Ericsson, Michael J. Prietula, and Edward T. Cokely in their article “The Making of an Expert” refer to this type of practice as deliberate practice. Geoff Colvin further develops the term in his book *Talent is Overrated*. Deliberate practice entails considerable, specific, and sustained efforts to do something you cannot initially do well if at all.⁴ Deliberate practice is designed specifically to improve performance, often with a teacher’s help. It needs to be repeated a lot; feedback on results must be given continuously; it is highly demanding mentally, and it is not much fun.⁵

The specific design aspect of deliberate practice requires a plan or design to execute. Most fields of endeavor have bodies of knowledge on how performance is developed and improved. An amateur simply trying things out or working on skills that he already knows is not drawing on this knowledge and his practice is not designed to utilize this knowledge to improve performance. Improvement without design is simply accidental. Dedicated practice requires purposeful training, not haphazard practice time. Usually, a teacher or coach can drastically improve the ability to deliberately practice. Teachers not only have a vast knowledge of the techniques needed to improve, they also are unbiased observers capable of determining the best practice activity to improve performance. One way of describing this process is to think of three concentric circles. The inner circle is the comfort zone. The middle circle is the learning zone, and the outer

circle is the panic zone. The comfort zone contains activities that are already mastered and the panic zone contains activities that are still out of reach and in which the student is completely helpless. Progress occurs when activities are chosen in the neither too simple nor too demanding learning zone. Only the learning zone contains activities that stretch the limits of one's skills and it is through this stretching process that improvement occurs. In addition to being at the correct level of difficulty, the activities need to be repeatable. High volume of repetition is key for building up new skills as well as improving on old ones. Repetition allows the building of consistency and eventually will imprint the feel of when the technique is used correctly.⁶

Continuous feedback is also necessary for deliberate practice because it is the only way to determine if the training is working. In sports, seeing the results of practice is very straightforward. For example, basketball players know very quickly if they make their shot. The feedback makes for immediate adjustments and corrections. Feedback continues in an endless cycle with the adjustments it requires. This process requires a fairly high level of concentration and focus that puts a high demand on even a mainly physical deliberate practice. This level of concentration is exhausting, and no one can sustain it for long periods of time. Four or five hours of deliberate practice seem to be the upper limit, and only the masters in a field reach this level. Two or less hours appears to be a much more consistent average sustainable deliberate practice time. This extreme level of concentration is exhausting and not much fun.⁷

Expert Pilot?

Since there are significant benefits to being an expert, and expertise can be taught,

the next step is to determine what makes an expert pilot and how can these skills can be taught. While “stick and rudder” skills are invaluable, they are actually rudimentary. To an expert pilot, they are second nature. The expert pilot performs the manipulation without thought and knowing where to position the aircraft in the sky becomes more relevant than how to get the aircraft into that position. The experiments of psychologist Daniel Gopher support this claim; Gopher had Israeli Air Force cadets play a video game called Space Fortress. The game exercised memory and attention by requiring players to maneuver a ship through a frictionless, hostile environment while firing missiles to defeat an enemy and avoid being shot. In one hour a day for ten days the cadets playing the game showed an almost thirty percent improvement in actual flight performance compared to the cadets who did not play.⁸ The video game did not teach real world techniques or procedures but instead challenged the players to improve memory and attention. The improvement in memory and attention over ten hours of play resulted directly in an improvement of thirty percent in actual flight training. Attention and memory help determine where to position the aircraft based on the environment and situation and are part of sound judgment. Therefore, sound judgment, not basic flying skills, is more relevant to expert pilot. Judgment is the “ability to judge, make a decision, or form an opinion objectively, authoritatively, and wisely, especially in matters affecting action; good sense; discretion.”⁹ More colloquially, judgment is the ability to make the “right” decision under conditions of uncertainty. The difficulty of judgment is determined by the time constraint, uncertainty, cognitive complexity, and stress of the situation.¹⁰ To exercise good judgment, an actor must overcome these four difficulties.

Decision-Making

To determine how to train someone to make good decisions, instructors must first know how people make decisions. The traditional view is that decision-making is done through rational analysis. The implication is that situations are analyzed and decontextualized to grasp the situation and allow a trainee to calculate the best solution. The traditional view was thought to apply even in time-critical decision-making. Rational actors quickly weigh options and decide. Modern studies of naturalistic decision-making are finding that outside the laboratory or the office the traditional theory rarely applies. In Klein's opinion, only specific areas, such as scientific or technological research, are appropriate for analytical decision-making. Rational thinking has limited applicability in most decisions because the rules are ambiguous and calculations difficult or impossible.¹¹

To illustrate this within aviation, every time a pilot lands an aircraft, there are infinite variations on speed and glideslope available. Based on the current environmental conditions, there may or may not be one "best" solution; the one decision for the pilot to find. Instead there are usually multiple solutions that satisfy the conditions of a safe landing. A pilot who attempted to find the perfect landing would run out of gas before a solution was found. By contrast a pilot who accepted satisfactory solutions would be able to practice multiple landings in the same time, each time gaining experience and building pattern recognition. This may seem obvious and the idea of a pilot running out of gas while searching for a perfect landing may seem far-fetched, but that is actually the point. People use experience and intuition to make decisions a majority of the time. Naturalistic decision-making is the study of how people use their experience to make

decisions in field settings. Understanding that this is actually how people think and make decisions is at the root of how to teach them to improve this skill.

Systems theory as well as complexity theory teaches that complex adaptive systems exhibit a phenomenon known as emergence where the sum is different or possibly greater than the sum of its parts. Robert Jervis in his book *System Effects* gives a simple example of this relationship using a piano. Each note, when struck independently, has a predictable nature, but when two notes are struck together, they create a chord with properties that are different from either note taken separately. The chord has a new attribute that no individual component had.¹² Analysis cannot break these systems down to find solutions; they are unpredictable, but despite their unpredictable nature, they are bounded and patterns can emerge.

Pattern Recognition

Pattern recognition is a quality of an expert and develops from experience, especially experience enhanced by deliberate practice. Pattern recognition and mental simulation are also the two pillars of naturalistic decision-making. Gary Klein discovered in his book *Sources of Power* that most decision makers, especially in high risk, time-critical positions, do not use analytical decision-making. In fact, when asked, most people did not even think they had made a decision at all. The primary study was of fire battalion commanders, making life and death decisions in the midst of fighting a fire. These commanders saw the situation, recognized a pattern from their experiences and could use that pattern to create mental simulations of what they should do next based on what they thought was happening. Since these actions seemed obvious and no other

options were considered, the commanders never recognized a decision point in the thought process. Figure 1 in Appendix B is a perceptual tool to illustrate Gary Klein's view of what sources of power enable people to make decisions.

Intuition

*“Intuition depends on the use of experience to recognize key patterns that indicate the dynamics of the situation. Because patterns can be subtle, people often cannot describe what they noticed, or how they judged a situation as typical or atypical.”*¹³

Intuition creates an emotional reaction to anticipated consequences of good or bad choices well before an individual consciously recognizes the options. One of the firefighter commanders studied by Klein was convinced he had ESP. He had evacuated a building seconds before the floor had collapsed and was convinced he had a sixth sense that had warned him. What Klein discovered was that the commander had subconsciously recognized minor details of the situation that stood out as atypical. He intuitively realized the fire had started in a different location from that originally thought and reacted by evacuating his men to safety all without ever realizing his own thought process.¹⁴ We will see how this lack of conscious recognition figures when applying the aspects of intuitive decision making to future training, but for now the focus will remain on how decisions are made.

Boyd's OODA Loop

Klein offers one perceptual model of how decisions are made, but his model fails to illustrate how the connections and decisions are actually made. A fuller and more

robust model of the decision process comes from John Boyd and his famous OODA loop. OODA stands for the four phases of the loop: observe, orient, decide, and act. The OODA loop is a mnemonic for what Boyd believed were the four phases of decision-making. Figure 2 in Appendix B illustrates the complexity of each step of the loop with each phase connected through feedback to the ones that came before.

The basic understanding of the OODA loop is that it is a decision-making process, and that the faster one can use this process relative to an enemy, the more advantage one gains over that enemy pilot. But this is an incomplete orientation to the OODA loop. The OODA loop is much less a model of decision-making and much more of a model of learning and adaptation for both individuals and, in an extended sense, organizations. Decisions are made, but they are made in the context of the situation and not in isolation. Examining Boyd's OODA loop while keeping in mind Klein's Sources of Power provides additional insight into how people make decisions and interact with the world.

The first step of the OODA loop is observation. Observation is the initial input. Boyd included unfolding circumstances, outside information, and unfolding interaction with the environment as inputs into the observation phase. The last of these is important enough to expand on briefly. The unfolding interaction with the environment is recognition that observing a system impacts the system. From Boyd's article "Destruction and Creation"¹⁵ we know that he based this concept on the Heisenberg Uncertainty Principle that stated you could not know both the speed and location of a particle at the same time as well as recognizing that observation of a system impacted the system. To use a more visual analogy, using a thermometer to measure the temperature of a cup of coffee will lower the temperature. While measuring, some of the liquid's heat

warms the thermometer, and thus the temperature reported diminishes. At normal temperatures this impact might be small and not significant for the needs of the measurement, but if the thermometer had been measuring the temperature of a freezer immediately before the coffee measurement, the temperature difference could be more dramatic. The impact of the observer on the system is also where the feedback from decisions returns to restart the loop. The extent that Klein's attributes of the expert apply to the observe phase are that experts making decisions would have better foreknowledge of the input required to make a good decision and would ensure that those inputs are observed prior to moving into the orientation phase. The temptation would be to use the aspects of Klein's expertise to describe how people observe the situation, but seeing things that are invisible to novices and seeing patterns, anomalies, and events that did not happen or may soon happen are all actually built from experience and they are actually part of the second phase of the OODA loop, orientation.

The orientation phase is the most important in the OODA loop. The sources of power for expert decision-making all exist in the orientation phase as well. Klein's attributes of expertise primarily result from pattern recognition, which is a simple way of explaining how people orient to a situation. A majority of the attributes of an expert are applied in the previous experience bubble within the orientation phase, but Boyd recognizes that there are other influencers included in orientation as well. He includes new information, novel items not previously experienced, as well as genetic and cultural filters. He also includes analysis and synthesis. Analysis is defined as the breaking down of something into pieces that may be easier to understand. Synthesis is the recombination of these broken down components into something new. People use all of these things to

create a perceptual model time after time.

Prescriptive Procedures

Expert decision makers need to deliberately practice the skills required to make sound decisions within their field of expertise and to do so often. They need to repeatedly practice the precise skills required to create the decision-making experiences needed to orient the problem correctly and analyze and synthesize the patterns into applicable forms. So, by understanding how people make decisions, we can see the immediate value of experience in the decision making process, but the experience must be specific to the area of the decision. If the experience is too far removed from the decision, then the decision maker will attribute the decision to a novel situation. A traditional view of the solution to this problem is to teach tactics, techniques, and procedures (TTPs). The assumption is that through these TTPs enough experience will be generated that eventually a pilot will be capable of making decisions, but the TTPs remove the requirement for decision by prescribing standardized solutions instead of teaching the novice pilot how to recognize the pattern and why the TTP is the solution to the problem. One example of this disconnect is learning to ride a bicycle by using training wheels. People do not use the training wheels so well that they become an ingrained part of the bicycle riding experience; they outgrew the need for training wheels. “Presenting procedures to trainees gives them a false sense of progress. This confidence dissipates when novices realize that applying the procedures depends on the context and no one can tell them what the context is.”¹⁶ To return to our landing aircraft example, the procedures for student pilots list a series of gates, a combination of altitude and airspeed,

which students should hit when approaching for a landing. Like the training wheels in the previous example, the gates are irrelevant to the actual landing requirements. The gates provide descriptive characteristics of one possible safe landing glideslope and closure rate. The evaluation criteria as well as the procedures taught focus on meeting the gates and not what the gates represent. Understanding of closure rates and glideslopes is expected to come when the landing process has been repeated enough times, but there is no discussion of what experienced pilots are seeing and doing versus the novices. Gary Klein solved this dilemma through a process known as CTA.

Cognitive Task Analysis: A Tool to Bridge the Gap from Theory to Application

CTA is a tool that attempts to translate how experts think into strategies for perceiving, or orienting the situation. CTA is the description of the expertise needed to perform complex tasks. It requires locating sources of expertise, evaluating the quality of the expertise, performing knowledge elicitation, processing the findings, and applying the findings.¹⁷ Traditional task analysis focuses on procedures used, but CTA moves beyond that into the perception, judgment, and decision-making skills of the experts in a field.

Step one of CTA focuses on identifying sources of expertise. CTA focuses on the expertise and not the experts themselves. The emphasis is to “find individuals whose expertise is respected in the organization, in order to learn how they see their job.”¹⁸ Step two is to assay the knowledge and determine its value and the cost to extract it. Not every piece of knowledge is worth the cost and time to extract, so step two allows for weeding out some data to focus the research. Step three is to extract the knowledge. This can be accomplished in a variety of ways including structured interviews,

interviews, or stories, about actual challenging events, interviews about concepts used to think about a task, and simulated tasks that require the expert to think aloud during performance or respond to questions after the event. Step four is to codify the knowledge, sort and organize it to make understand what it means. Understanding the decision requirements as well as what makes the decision difficult can allow trainees to apply the information in more practical ways. The final step is to apply the knowledge.¹⁹ The key cues for problem diagnosis have been identified; now they just need to be taught and applied. By understanding the expert perceptions and how they perceive the task, relevant training can be created to teach novices to think like the experts. Once the proper training exists, dedicated practice and repetition can enable the possibility of expertise.

CTA is a tool that may be utilized to understand how experts think about the tasks they perform and provide insight into how to train less experienced people to think like the experts. The video game Space Fortress and its impact on the Israeli Air Force show the significant impact of training novice pilots in skills that are the most relevant to their success. Space Fortress has moved beyond aviation to basketball. The 2006 NCAA champion Florida Gators used it.²⁰ The improvements of memory and attention appear to benefit any field that requires numerous, rapid, strategic decisions. A CTA study should capture the most relevant skills needed to be an expert pilot, such as those from the Space Fortress game, and should be conducted to capture the current expertise in military aviation. Considering the last ten years of war now is a prime time to find experts whose actual combat experience could directly contribute to applicable future training for Naval and Marine Corps Aviators. The CTA may need to be broken down into general

aviation, fixed wing and helicopter, and possibly as far as specific aircraft to gain the full benefit.

Conclusion and Recommendations: Think Like an Expert

So far this study explored the desired outcome of expert pilots, examined what it means to be an expert and showed why expertise is beneficial. It continued with an examination of judgment and how people make decisions that drove the discussion back into the impact of experience on the ability to make sound decisions. The US Navy should use CTA to study its expert pilots to enable training to increase pilots' beginning capability for effective intuitive decision-making. A professional analysis of how expert pilots think about their skills and decisions will significantly enhance the naval aviation community understanding. The argument concludes that effective intuitive decision-making is the primary attribute of expert pilots, but this claim might make some people uncomfortable. Intuitive decision-making implies that intuition provides the best answer to most flying choices instead of rational calculation and by-the-book knowledge.

Appendix C addresses the risks of intuition and how to mitigate those risks.

Unfortunately, no data exists to accurately predict the results of implementing a training program based on this theory. The theories are all based on scientific study, but their focus was on understanding how people think, make decisions, or become experts, and is not focused on developing an educational methodology that can be tested to improve future performance. The synthesis of these theories provides a foundational theory for future application, but testing is still required to prove the theory's soundness and demonstrate a numerical advantage.

The anticipated advantages are less tangible than an immediate reduction in flight hours or training time, although those benefits may occur as well. The primary expectation is that a shift in training methodology will bridge the gap between the end of traditional flight school and when a pilot becomes an expert. Many liberal arts colleges claim that they do not teach students what to think, but rather how to think. They see the benefit in education not just in the accumulation of knowledge, but also in learning the skills needed to gain future knowledge. By providing additional training for the instructors in flight school to enable them to teach novices about how the experts think, the expectation is that the novices will not only learn the basics of flying but also the techniques needed to continue to improve after they leave flight school. By learning how to learn like an expert, the pilot increases his ability to train effectively toward expertise.

Application of these recommendations requires a CTA study of expert Naval pilots followed by improved training of the instructors to teach them better techniques for explaining procedures to the student pilots. No additional student training time is anticipated. In fact, if the Space Fortress game is any indication of possible effectiveness of using the correct techniques, training time might actually drop. Whatever the student training time becomes, the expectation is that the students who graduate would be better prepared to harness their experiences in their operational squadrons and become expert pilots. There is additional hope that the students will benefit from the shift in training focus during flight school, but there is currently no way to determine if the effects will manifest within the flight school training.

The Navy needs expert pilots who can react quickly and intuitively in complex situations to execute sound judgment. Expertise provides unique capabilities of pattern

recognition and mental simulation that enable accurate intuitive decision-making.

Accurate intuitive decision-making is necessary to have sound judgment, especially in time critical situations such as aviation. Intuitive decision-making relies on experience and expertise, so training specific skills over time builds the foundation. CTA is a tool that is available to decipher the exact skills needed for dedicated practice to create expertise. Based on the skills needed and an understanding of the intuitive decision making process, improvements can be made to the flight training program that should improve the ability to create and train expert pilots.

APPENDIX A: The Expert Advantage

To understand the goal of creating expert pilots, it is essential to understand expertise, what it is, and is not, and why it is desired. Gary Klein explains in his book *Sources of Power* that “One view of experts is that they have accumulated lots of knowledge.”²¹ While this view is correct in the basic concept that experts have more knowledge, it creates a false image. Experts have not learned all there is to learn even within their field, they just understand the field well enough to learn differently than a novice. If the knowledge of an expert were pictured as a library, the vastness of the library alone is not enough. The knowledge must be organized to provide easy access to the vast stores. This ability to organize the knowledge available enables experts to effectively see things that are invisible to the novice. Experts are able to see patterns that novices do not notice, anomalies, events that did not happen and other violations of expectancies, the big picture (situational awareness), the way things work, opportunities and improvisations, events that either already happened (the past) or are going to happen (the future), differences that are too small for novices to detect, and their own limitations. All of these aspects can be derived from pattern matching and mental simulation.²²

Pattern matching applies to being able to see patterns that novices do not notice as well as seeing anomalies. Novices cannot see relationships that are obvious to experts. For example, an expert fireman commander can look at a burning building and envision the structure, such as stairs, elevators, and support beams, and can envision what is happening inside the building.²³ Pattern recognition gives one expert fireman enough subconscious situational awareness that he is able to evacuate a building just before the floor collapses. Because there were anomalies to the pattern of the fire, the fireman felt

that there was something different or wrong. The fire was not progressing the way it should based on where it was thought to be. The anomalies were so subtle that they were not consciously recognized, but the fireman's expertise allowed him to register the anomalies subconsciously and react to the pattern he recognized intuitively.²⁴ This ability of experts to see the pattern enables their overall ability to see the big picture or maintain situational awareness. A novice is much more likely to get bogged down in the details of the situation and lose sight of the big picture.²⁵ Pattern matching enables an expert to analyze a situation into parts that are easier to visualize and track.

Mental simulation allows experts to see inside events and objects and understand the way things work. They have mental models of how things are supposed to be done and can quickly see if they are not going as expected. These mental models also enable the expert to take advantage of or create opportunities or improvisations.²⁶ In military aviation, these opportunities are essential to be able to recognize and exploit an enemy mistake or utilize an advantage. By recognizing the pattern and being able to mentally model what is happening, experts see opportunities that a novice pilot would not recognize. The ability to anticipate the past and future from a snapshot is also directly related to the expert's ability to model the situation mentally. This ability is also fundamental in the ability to look at the world through someone else's eyes. Being able to reorient to another person's perspective gives a significant advantage when in an adversarial engagement such as an aerial dogfight. If you can put yourself in your opponent's place, you can anticipate what he might do next based on what he perceives.²⁷

The ability to make fine discriminations and the ability to manage one's own limitations stem from an increase in the situational awareness that increases as someone

gains expertise. The exact method of this increase is not fully understood, but the effects are clear.²⁸

What this means in terms of naval aviation is that there are significant concrete advantages to having expert pilots. The expert pilots will be able to recognize patterns and pick up on anomalies that will increase the safety of the flight. The ability to organize and process the relevant data enables them to make sound decisions more quickly than a novice. The ability to reorient to an adversary's perspective enables the expert pilot to predict the adversary's behavior and anticipate and exploit opportunities.

Rather than expertise being the accumulation of more and more knowledge, expertise is learning how to perceive more; the knowledge and rules are incidental. By focusing on how to build and recognize patterns instead of focusing on procedures to follow, people can be trained to achieve expertise more quickly. Rules, facts, and tactics, techniques, and procedures (TTPs), vice intuition, have previously dominated the efforts in the field of technical training. Skills and knowledge are seen as a set of procedures to be deconstructed and taught systematically. This strategy is effective for simple, procedural tasks, but they are not designed to gain higher levels of expertise or judgment. Teaching procedures gives novices a false sense of confidence that dissipates when the novice realizes that the procedure is still dependent on the context in which it is applied and the context cannot be taught. Judgment and decisions are rarely straightforward and if the goal is to teach people to think like experts we must understand how the experts are thinking, including their strategies and perceptions.²⁹

APPENDIX B: FIGURES



Figure 1 - Klein's Sources of Power^{30,31}

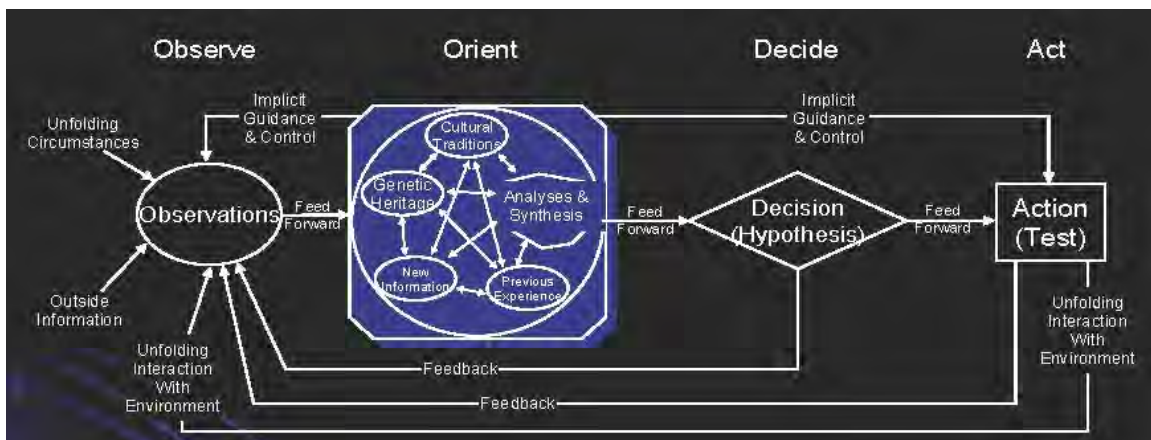


Figure 2 - Boyd's OODA Loop³²

APPENDIX C: The Risks of Intuition Addressed

While intuition is based on experience, experience does not imply that intuition is infallible and addressing the common illusions of intuition is essential for mitigating them in training designed to improve intuitive decision-making. Three everyday illusions of intuition are the illusions of attention, memory, and confidence.

The human mind has an incredible capacity to focus on essential tasks while ignoring all irrelevant information. This capability is also the source of the illusion of attention. In a psychology experiment in the 1970's a video is shown of two teams of basketball players passing the basketball. One team is in white and the other black. An observer is asked to count the number of passes made by the white team. Halfway through the video a girl in a full body gorilla suit walked into the middle of the scene, stopped in the middle of the players, faced the camera, thumped her chest, and then walked off after spending nine seconds on the screen. Roughly half of the observers never saw the gorilla. The invisible gorilla, as the experiment has become known, is a primary example of the illusion of attention. The illusion is that people experience far less of the visual world than they think they do. Similar experiments exist of pilots in simulators focusing on a task such as using a head-up display (HUD) and missing an airliner pulling onto the runway where they are landing. The more mentally complicated the focused task the higher the percentage of people who experience the illusion of attention. In other words, the more complicated the task the more attention people focus on it and the less attention is available to notice something unexpected. For pilots this would be described as a loss of situational awareness. The solution to the dilemma of the invisible gorilla is expertise. Experienced basketball players are much more likely to

notice the gorilla in the basketball-passing video, but team handball players are not.

Expertise helps you notice the unexpected, but only within the context of the expertise.³³

As Gary Klein covered in his attributes of expertise, one of the qualities of an expert is the ability to see the invisible, in this case see the invisible gorilla. To teach this ability requires that attention be drawn to unexpected objects that are missed.

The illusion of memory is defined as the disconnection between how people think memory works and how it actually works. People believe that memory is immutable, acting as a permanent and accurate recording of what happened, but in reality memory depends on a combination of what actually happened as well as how one made sense of what happened in context of all experience. This reservoir of experience is constantly in flux. The mind is quite capable of filling in the blanks in a memory to what one thinks should be there. For example, if someone saw a picture of an office with desks, chairs, shelves, and other office equipment and were asked later to recall the image there is a good chance that books and filing cabinets not in the image would exist in the recall because by defining the image as an office the items *should have* been in the image and their absence is incongruent with the way people make sense of the office image.³⁴

The most relevant issue of the illusion of memory to flight training is that so much of the training provided comes from explanations of the flight instructors who have enough experience that their skills have become intuitive and they no longer truly understand what techniques they use to be so effective. The CTA is an unbiased method for an outside observer to extract the truth from the memories and skills of the expert pilots. The analysis will then provide a valuable new language to instruct the novice pilots. The risk is that so much of CTA comes from the memories of the expert pilots

themselves through interviews and stories. The use of memories must be combined with the use of other techniques such as observing the pilots while watching videos or operating simulators to track eye movements and verify key inputs into their decision process. By combining the experiences of enough expert pilots with experimental data analysis on relevant inputs, the CTA will be much more likely to produce accurate perceptions and skills necessary for success.

The final everyday illusion to be discussed is the illusion of confidence. The illusion of confidence comes in two forms. The first is that people who appear confident are trusted more, and, second, people believe they are underrated. The illusion causes people to overestimate their own qualities especially relative to other people as well as judge competence based on the appearance of confidence. The caveat to this illusion is inversely proportional to the skill of the individual, so the least skilled are most likely to be overconfident. People tend to think that good performances reflect superior abilities while excusing poor performances as a result of circumstances outside ones control. Teaching someone how to improve on a task, however, has proven to significantly reduce overconfidence. Making people more competent increases their ability to judge their own competence. Incompetence causing overconfidence tells us that study and practice of a task allows people to improve in the task as well as knowing how well they perform the task. When people learn new skills their skill level is low and confidence is higher than it should be. As their skills improve their confidence also rises, but at a slower rate than their skill, so eventually the skill level and confidence match.³⁵ Awareness of this illusion is key to understanding the associated risks. Flight training is inherently dangerous and becomes more so when students and instructors are unaware of some of

the risks. Overconfidence is not an unknown risk, but targeting specific skills needed to create expertise can build the experience necessary to improve skills and reduce the risk of overconfidence.

¹ F. Brecke, "Instructional Design for Aircrew Judgment Training," (Oct 1982, 145-160), www.faa.gov/library/online_libraries/aerospace.../sd/.../brecke_f.pdf (accessed Oct 28, 2011), 145.

² K. Anders Ericsson, Michael J. Prietula, and Edward T. Cokely, "The Making of an Expert," *Harvard Business Review* (July-August 2007), http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCYQFjAA&url=http%3A%2F%2F141.14.165.6%2Fusers%2Fcokely%2Fericsson_Prietula_%26_Cokely_2007_HBR.pdf&ei=UAsjT6yKOOjt0gHe7KHiCA&usg=AFQjCNHRjOgpfH5udV1i30cRPQKZL2DT0A (accessed Jan 27, 2012), 2.

³ Ericsson et al. 1.

⁴ Ericsson et al. 3.

⁵ Geoff Colvin, *Talent is Overrated: What Really Separates World-Class Performers from Everybody Else* (NY: Portfolio, 2010), 66.

⁶ Colvin. 67-70.

⁷ Colvin. 70-72.

⁸ Sian Beilock, *Choke: What the Secrets of the Brain Reveal about Getting It Right When You Have To* (NY: Free Press, 2010), 86-88.

⁹ <http://dictionary.reference.com/browse/judgment>

¹⁰ Brecke. 147-152.

¹¹ Klein. 260-264.

¹² Robert Jervis, *System Effects: Complexity in Political and Social Life* (Princeton, New Jersey: Princeton University Press, 1997), 12-16.

¹³ Klein. 31.

¹⁴ Klein. 1-35.

¹⁵ John Boyd, "Destruction and Creation," unpublished essay (September 1976) www.goalsys.com/books/documents/DESTRUCTION_AND_CREATION.pdf (accessed Jan 30, 2012), 1-8.

¹⁶ Klein. 169.

¹⁷ Klein. 169-170.

¹⁸ Klein. 171.

¹⁹ Klein. 171-175.

²⁰ Beilock. 86-88.

²¹ Gary Klein, *Sources of Power: How People Make Decisions* (MA: The MIT Press, 1999), 147.

²² Klein. 148-149.

²³ Klein. 149-150.

²⁴ Klein. 31-33.

²⁵ Klein. 152.

²⁶ Klein. 152-154.

²⁷ Klein. 155-157.

²⁸ Klein. 157-161.

²⁹ Klein. 168-169.

³⁰ Klein. 289.

³¹ <http://openlearn.open.ac.uk/mod/oucontent/view.php?id=403128§ion=3.2>

³² Frans P. B. Osinga, *Science, Strategy and War: The Strategic Theory of John Boyd* (NY: Routledge, 2007), 231.

³³ Christopher Chabris and Daniel Simons, *The Invisible Gorilla: And Other Ways Our Intuitions Deceive Us* (NY: Crown, 2010), 1-42.

³⁴ Chabris et al. 43-79

³⁵ Chabris et al. 80-115.