U.S. NAVAL RESEARCH LABORATORY

Intellectual Readiness for Emerging Technologies

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FINAL REPORT

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PREFACE

This study was conducted for the Office of Naval Research under funding document N0001420WX00947. Technical cognizance for this task was assigned to CDR Jacob Norris, PhD, Warfighter Performance Department, Code 34.

Executive Summary

The rapid development of advanced technologies by near-peer adversaries has the potential to change the status quo of United States' security. Efforts to accelerate the pace of technological development in the US Department of Defense dominate the current research and development enterprise, as evidenced by significant expansion of the DoD's science and technology budgets for both fiscal years 2020 and 2021. These investments are primarily limited to technological developments, however, which has caused growing concerns about whether or not the US military's most valuable resource—its people—are receiving adequate attention.

Speculations about conflicts with a technologically adept adversary feature complex scenarios that challenge or render obsolete legacy tactics and strategies. Conditions of tomorrow's prospective battlefields depict a game that rewards those who can see patterns and connect ideas quicker, and who can capitalize on opportunities afforded from new technologies faster than an opponent. These kinds of conditions are ones that favor mental flexibility and creative adaptation over rote memorization and practice. Yet there are growing concerns that current education and training strategies for personnel reduce divergent thinking; that current manpower and promotion systems narrow rather than expand opportunities for creativity; and that commanders who dare to explore new ways of operating are more likely to have their deviance from standard operating procedures interpreted as insubordination rather than praised as innovation.

Creating a force that is not only technologically equipped but also intellectually adaptable requires manpower, personnel and training systems that allow and encourage heterogeneous thinking, and an organizational culture that supports innovation from the ground up, rather than imposing top down constraints. To identify how this can be accomplished in a large vertically-oriented organization like the US Navy, this project sought to define both the individual and organizational characteristics that enable and support innovation. To accomplish this, I sought out a representative sample of experts in innovation and emerging technologies in order to learn from their perspective what it means to be intellectually ready.

Creative insights and technological innovation often originate from perspectives that radically differ from the status quo. Therefore, it was important to ensure my sample was both broad and diverse, spanning not only specific domain knowledge, but also stretching across time. The US Navy has wrestled with the growing pains of emerging technologies many times before. For example, at the turn of the 20th century, aviation was considered an emerging technology; one which profoundly challenged the preexisting identity of what a Navy fundamentally was, and ultimately ushered in a new era of sea power in the form of the aircraft carrier. Hence, I began by interviewing authors and historians who specialize in the history of Naval innovation. Additionally, new technologies and concepts that are being tested today represent a glimpse into potential near-term challenges and hurdles that our current systems may present. Accordingly, I interviewed active duty sailors working with emerging technologies such as robotics, autonomous systems, and the newest classes of guided missile destroyers and submarines. Lastly, technologies whose capabilities are still largely hypothetical, such as quantum mechanics and synthetic biology, are instructive of the kinds of major paradigm shifts that may be necessary in the not-too distant future. To capture this futuristic perspective, I interviewed scientists and engineers who specialize in emerging technologies such as quantum computing, hypersonic weapons, and artificial intelligence. Together these interviews generated over 114 hours of transcripts. Combined with an in depth literature review from cognitive and behavioral psychology, neuroscience, business management, and team science, I developed and validated the 12-factor model of intellectual readiness for emerging technologies.

Intellectual readiness can be considered the mental and psychological equivalent of physical readiness. The concept suggests that people who are mentally prepared and trained, and ideally supported by their environment, will be most capable and effective in the face of adversity or uncertainty. Individual attributes such as teamwork, situation awareness and mental resilience have long been considered central to the preparedness of military personnel, and these attributes featured prominently in this model. Other attributes, such as intellectual curiosity, pattern recognition and far transfer learning represent new perspectives of what tomorrow's Navy might want to emphasize and teach its sailors and leaders.

While the specific mental and psychological attributes identified in this model are empirically valid and ecologically sound, the concept of intellectual readiness most certainly extends far beyond preparing any one individual. Arguably, no matter how prepared individual sailors are for uncertainty and complexity, the organizational culture and supervisory influences that surround that individual will determine the extent to which that preparation is effective. Accordingly, intellectual readiness is not merely an individual goal, but an organizational one as well.

The single largest barrier to the US Navy developing true innovation is not a lack of novel technologies or trained individuals; it is the abundance of internal resistance to change and systems that serve to reinforce the status quo rather than enabling and fostering innovation. This does not merely apply to bureaucratic structures or business processes, but extends deeply to include the central role that mid-level managers play in allowing new ideas to survive and flourish, and the standards with which personnel are assessed and promoted. Every officer is a product of the system that promoted them. For an individual to be able to try something new, or to respond to novelty in a productive manner, they need to believe their deviance from standard operating procedures will be celebrated as innovative, and not punished as non-compliant. They will need to believe that the results of their imagination and willingness to experiment with new ideas, if successful, will be adopted and used, and not discarded or blocked. Teaching people how to "think outside the box" is only valuable if the "box" is not considered sacred.

The operational environments of tomorrow should dictate how we prepare today. New currents and winds open new routes and new opportunities to captains who are bold enough to explore the unknown. The results of this original research provide a clear picture of what intellectual readiness is, and how it can be achieved.

- ES Vorm, PhD

U.S. NAVAL RESEARCH LABORATORY

1. Introduction

1.1. What is Intellectual Readiness?

The traditional hardware-focused prioritization of technical skills in the Navy is fast becoming outdated. Software is the currency of tomorrow's technological market, and the language spoken in that marketplace is digital, not analog. Motivated in part by a steep increase of complex technologies replacing older legacy systems, many lawmakers and strategists have insisted that the US Navy needs to refocus its efforts on preparing its people with the same rigor it does preparing its machinery.

In light of concerns that the USA is falling behind other countries such as China in terms of STEM education and digital literacy, a 2017 report by the Defense Innovation Board recommended sweeping changes to the manpower, personnel, training and education (MPT&E) pipelines in order to prepare for the forecasted digital transformation of the workplace. The report called for a renewed focus on recruiting STEM talent, providing more educational opportunities to service members, recommended creating a career track for computer scientists, and even went so far as to recommend that higher education be included as criteria for promotion in key ratings and designators. The 2019 Workforce Now study by the Defense Innovation Board again pointed to the looming "digital readiness crisis," and called for immediate actions by Department of Defense (DoD) leaders to augment and expand recruiting and retention efforts of STEM and digital-focused career fields. Significant barriers to retention, such as lack of career flexibility, insufficient opportunities for development and promotion, and an overly restrictive environment that is closed to innovation and exploration, make the DoD less competitive, and discourage talented individuals from joining or remaining in the service.

Simultaneously, the emergence of several new technologies, such as AI-infused cyber weapons, quantum computing, hypersonic weapons, synthetic biology, and a wide array of autonomous systems have introduced new dimensions of complexity into the technological ecosystem—all of which are completely new and represent a large amount of uncertainty for warfighters. Speculations about what warfare with a near-peer adversary may look like involving these new technologies has prompted a multitude of concerns over the DoD's readiness posture--specifically the readiness of its most important asset, its people.

AUTONOMY			
	Programs with Autonomy Components	**Dedicated Programs**	**TOTAL**
Basic Research (6.1)	3,080	2,676	4,075
Applied Research (6.2)	7,320	7,066	10,931
Advanced Research (6.3)	5,139	4,589	8,438
ARTIFICIAL INTELLIGENCE			
	Programs with AI Components	**Dedicated Programs**	**TOTAL**
Basic Research (6.1)	1,727	3,157	3,880
Applied Research (6.2)	2,878	2,547	5,587
Advanced Research (6.3)	1,281	201	2,098

TABLE 1: US Military Science and Technology budget related to autonomy and AI, by research category (USD in millions, FY2018-FY2020)[1]

1 Source: Department of Defense FY2020 Budget Estimates, RDT&E Justification Books of the U.S. Army, Navy, Air Force, and DARPA.

In addition to the potential shortcomings of existing hardware and software, concerns have also focused on the enduring value of personnel who are cognitively and psychologically prepared to handle uncertain and challenging futures. Existing training that reinforces known patterns and rote memorization, and deemphasizes critical thinking and creativity is a poor recipe for responding to unknown and unanticipated threats. Conversely, a fighting force comprised of psychologically resilient, competently trained and educated minds who are empowered to think flexibly and creatively is the best antidote against uncertainty.

1.2. Technological Effects on Organizational Culture

As early steam engines gave way to diesel and later to nuclear power, discussions about the hiring and training of people capable of working on, with, and around complex technologies has always been dominated by an idea of aptitude. People who have the "right stuff" are ones who can learn quickly, leverage technology effectively, and execute when called upon to do so. Today's technological changes are in many ways similar to those from earlier epochs, with two notable exceptions: many of today's technologies are capable of increadible levels of perception and decision making (e.g., thinking) and learning, which means that their operations are not fully scripted and therefore we cannot determine exactly how they will behave under every conceivable circumstance. Add to the equation the fact that the US is facing an adversary that is as large or larger, and whose technical prowess meets or possibly exceeds our own, and the prospect of future combat is one colored by a great deal of complexity and uncertainty.

The military of tomorrow will feature less payload-centric, remotely piloted “unmanned” platforms, and will instead feature autonomy centric, robotics platforms that enable Human-Machine teaming. The difference may appear subtle, but it actually portends large changes in terms of how the US military mans, trains, and equips its people. To best understand how this shift occurs, refer to Figure 1, which describes the ripple effect of new technologies on organizational structures and cultures.

When a new technology, such as an autonomous system, is introduced, the principles that govern its use are typically inherited from earlier technologies. These are carry-overs at first. Some groups who get the technology in their hands and experiment with it begin to make it work in context. In doing so, they discover effective practices, or ways of leveraging the technology in new ways to obtain new advantages or capabilities. Those practices, however, are informed by principles that they've already embraced, which are the overarching concepts that govern their approach to a new technology, and they can only be developed if they are allowed sufficient leeway to experiment and explore the technol-

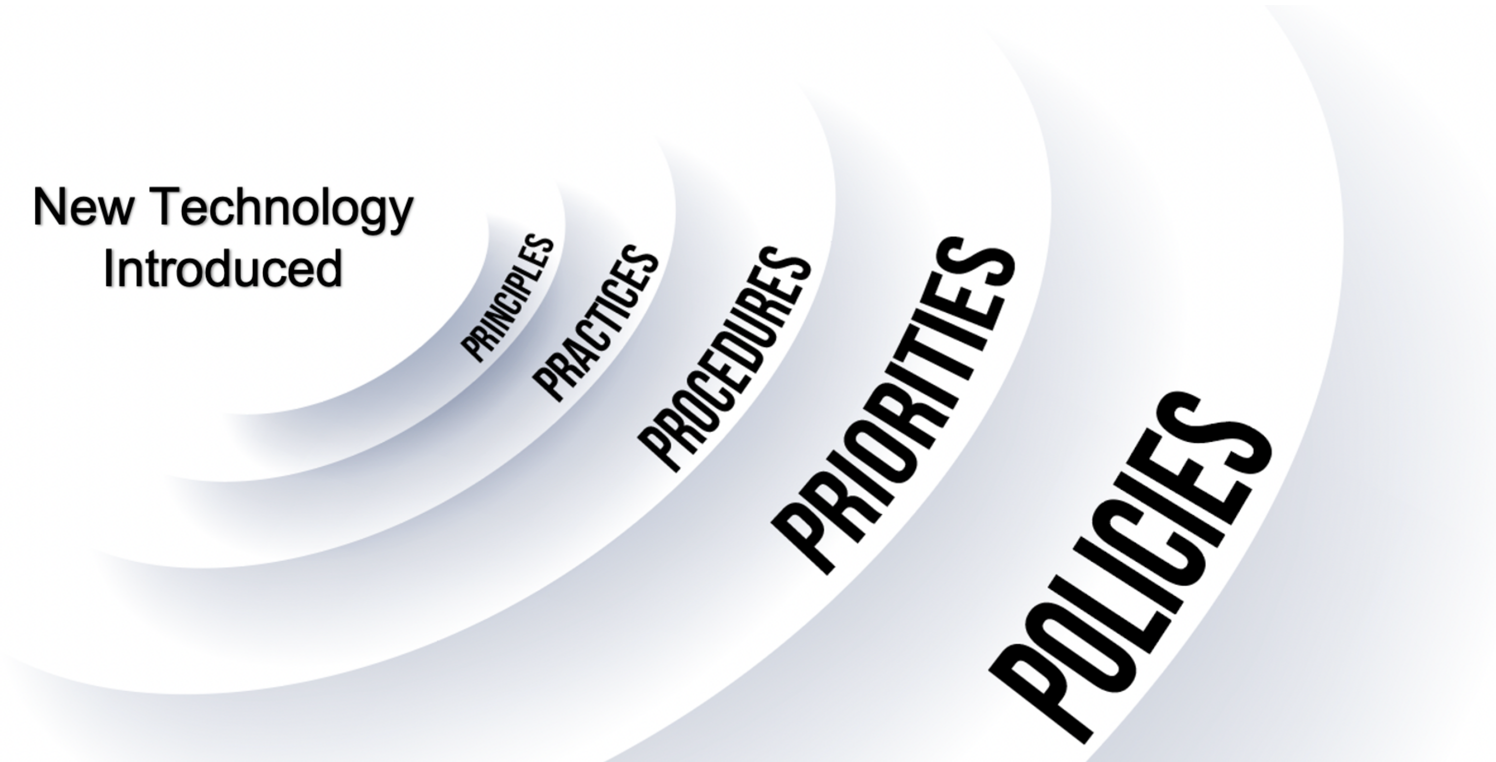


Figure 1: Vorm's 5-P model of technological effects on organizational culture.

ogy. If such opportunities are afforded and sufficient experience is gained, practices will begin to be documented as standardized procedures. At that point, the technology will become established and begins to feed back into higher levels of governance, which in turn begin to change priorities in the form of budgets, planning, strategies, etc. These become codified into policy is the top level, and once this is accomplished, force structures and other broad concepts have been effectively changed--and those changes can all be traced back to the introduction of the new technology.

Recall, however, that there were *conditions* that govern whether these ripple effects translate to one another. Merely investing in new technology, no matter how remarkable, will not necessarily yield technological advantage **unless the ripples are allowed to spread**. The conditions that govern these processes come from the environment itself, which in this metaphor is the organization.

Principles constrain practices, and practices are what determine how things will be done. Organizations that strictly prescribe how technologies will be used, for example, by subscribing to contracts that ensure no Navy sailor will be able to physically touch or alter any component so that the technology can only ever be used as-is, will constrain that technology's use (and hence its potential benefit). No matter how well that technology was conceived and built, there will always be room for improvement. In some cases, such as in times of necessity brought upon by armed conflict, making those improvements may mean the difference between winning and losing the battle. Organizations that attempt to manage innovation in a linear top-down fashion actually disrupt any opportunty for innovation because of a phenomenon Enrico Fermi called the "will to think" (Westrum, 2004). In simple terms, this can be expressed as the following:

Your ability to think is predicated on your perceived ability to act.

The effect that the environment has on people's creativity is profound. People who work in organizations whose culture is open and welcoming to new ideas are more likely to generate new ideas and to innovate. Conversely, people that work in organizations whose culture is hostile towards innovation or disincentivizes trying something new are not only less likely to offer up new ideas, their ability to conceive of new ideas will be fundamentally constrained.

1.3. Emergent properties of complex systems

An argument can be made that the predominant engineering strategies of the past 100 years have sought to minimize and limit the influence of humans in any complex sociotechnical system (Norman 2016). Increasing levels of automation, originally conceived to relieve humans of the burdens of repetitive and dangerous work, are increasingly justified as a means of reducing human error, and it is easy to understand why. When compared with many of today's technological systems, human capabilities pale in comparison. Computers are faster and more powerful than humans. They do not get tired, bored or distracted. They do not have bad days, which means computers are less variable and therefore are more reliable than humans at discrete tasks. This perspective is remarkably popular in systems engineering, and often underscores the motivations of development efforts: the sooner we can fully automate our systems, the sooner we can eliminate errors attributed to humans. This perspective is also remarkably shortsighted, and ignores one key fact: the variance in human performance is not always a weakness, and in some cases is decidedly advantageous.

Low variability is highly desirable in environments that are stable because it means that you can test and validate systems to a high degree of precision, and that their performance in the real world will be true to specifications--so long as the conditions in the operational environment closely resemble the conditions under which the system was tested. In highly dynamic environments, however, stability can become a stumbling block. In these environments, plasticity and adaptability are more desirable(Charmantier 2008,Davidson 2011,Leggett 2013). When you consider the characteristics of humans that remain unique--context awareness, intuition, non-linear thinking, abstract reasoning--you can see tremendous benefits in evolutionary terms.

Modern human beings evolved over 200,000 years to be well-suited to constantly changing, dynamic environments and constraints. This adaptability, also called phenotypic plasticity, is the reason why humans are able to thrive in all of the climate zones of the earth, and able to live under remarkably variable conditions. Human cognition has also evolved in a variety of useful ways that are salient to conversations of dealing with complex and uncertain environments. Consider the following sentence:

Human beings are excellent at repairing information

Even flipped backwards and upside down, your brain can make sense of the words and understand their meaning without any special training or preparation. Similarly:

Yuo cna porbalby raed tihs esaliy desptie teh msispeillgns

These are simple examples that demonstrate the remarkable adaptability of the human brain. There are many, many more. And while there are many defensible arguments for removing human beings from certain elements of high-risk systems, it is important to recognize that these decisions, under certain circumstances, may not be wise.

When it comes to designing complex systems, a common approach bred by the perspective of humans as the weakest link in a system's chain is to adopt a top-down approach, one that produces constraints meant to ensure safety by controlling or mitigating the remaining variance. A good example of this might be the design of traffic intersections. A four-way intersection with sufficient amounts of traffic in the United States will commonly feature traffic lights. These traffic lights impose structure on an otherwise unstructured intersection, and thereby provide a means of reliably controlling human behavior. But this decision has an unintended consequence: it constrains the natural ability to cooperate and self-organize. Under ordinary circumstances, when the environment is stable, traffic lights work as intended and provide a high degree of stability and predictability. But when the environment becomes unstable, such as during a power outage at rush hour in Washington, D.C. the strengths of the system quickly become vulnerabilities.

PERFORMANCE	ENVIRONMENTS		
		Highly Stable	Highly Dynamic
	Variable	✗	✓
	Non-Variable	✓	✗

Table 2: Phenotypical plasticity is favored in dynamic and unstable environments, and results in resilient and adaptable systems.

Traffic circles, also known as roundabouts, are more commonly seen in European roadways, but are gaining popularity in the United States as well. Their design makes deliberate use of drivers' ability to cooperate and self-organize their behavior. In other words, constraints are introduced by the driver's themselves (e.g., bottom up), rather than arbitrarily imposed externally. A major benefit of this design is that it is highly resilient to dynamic changes to the environment. Power outages have no effect, and even under high volumes of traffic, roundabouts continue to function with almost no loss in throughput, and performance improves in relation to the knowledge and skill of drivers, which relates to the frequency that drivers experience roundabouts (in areas where roundabouts are common, throughput and performance is remarkably stable despite volume of flow).

Examining the differences in design decisions between traffic circles and traffic lights is a convenient way of examining the tradeoffs between top-down and bottom-up approaches to designing complex sociotechnical systems. Both pursue the same goals of reliability and predictability, but one does so at the expense of adaptability, while the other does not. Traffic lights work great under normal circumstances, e.g., when the environment closely resembles the conditions envisioned when the system was designed, but they cannot tolerate environmental fluctuations. In this sense, traffic lights are less resilient systems than traffic circles, and the difference in resilience is directly tied to the role of humans in the system. Traffic lights seek to reduce human variability (e.g., increase safety) by imposing controls; they see humans as weak links to be engineered out of a system. Traffic circles, on the other hand, fully integrate humans into the design by relying on their knowledge, expertise, decision making, and ability to self-organize; they see humans as capable and valuable components in the system.

If we move beyond discussions of systems engineering and return to a higher level, we can see shadows of these same decisions in how organizations decide how to structure themselves and address the constant need to change. Responding to uncertainty means being able to change; being able to pivot and adapt to new information, new circumstances, and new operating parameters. This is especially true in situations that feature high amounts of uncertainty and unpredictability; situations that are common in times of war. How an organization innovates, or rather from where innovation is expected or designed to come from, has consequences that mirror the design consequences mentioned above.

Highly vertical organizations, or those whose structures reinforce well-defined hierarchies, often feature a top-down approach to innovation. New ideas, technologies, and techniques are expected to come from the highest levels, and are delivered to the lowest levels via a well-organized system of checks and balances. Updates to existing systems are intended to be made via a feedback loop whereby operators can express their needs to higher echelons which adjudicate and prioritize what changes will be made (Westrum 2014). This approach is a reasonable way of managing complexity, especially in large organizations with multiple directorates of competing priorities and varying timetables.

But this approach, like the traffic light example from before, also favors highly stable environments and does not incorporate individuals very well into its design. Ideas that originate from anywhere other than the top--no matter how innovative or ground breaking-- have a difficult time surviving; many are seen as nuisances, distractions, or even as hostile to the organization, and are therefore crushed before they can take hold. Changes in the environment that require quick adaptations are harder to make because the many levels of checks and balances, all made up of groups of individuals with their own ideas, competing priorities, and sometimes territories to protect, must approve changes to existing procedures.

affects those individuals' ability to use those traits would be highly inefficient. At the least it would only ensure that groups of highly capable and innovative individuals remain frustrated and defeated in their attempts to improve and prepare their organization. At worst, in times of critical need, those individuals may find themselves unable to respond or adapt.

Figure 2: Traffic lights and traffic circles. Both improve safety, but one does so at the expense of resiliency to dynamic environments.

More importantly, recall from earlier that the ability of a person to think is predicated on their perceived ability to act. Organizations that routinely demonstrate an unwillingness to accept new ideas from lower levels, or who punish any variance from the standard way of doing things will effectively teach their people a kind of learned helplessness (Seligman 1972,Landry 2018,Maier 1976). These organizations effectively condition their people against using their creativity to solve problems, after all, innovation is ordained from on high; a kind of "father knows best" approach to innovation. In a very real sense, organizations that feature a top-down approach to innovation are conditioning their people against the very evolutionary behaviors that enable them to respond appropriately to uncertainty and dynamically changing environments (Mercier 2011).

1.4. An Innovation Ecosystem

To bring the discussion full circle, recall that the origin of concern is the potential for near-peer conflict in the future, which will undoubtedly feature new technologies and tactics that have never been modeled before and are therefore unknown. The desire to create an intellectually ready force is primarily motivated by two features: uncertainty, and complexity. Determining what knowledge, skills and abilities are necessary for service members to be able to handle these new technologies and respond to these technological challenges is the cornerstone of a coherent and unified manpower, personnel, training and education strategy. But as illustrated above, focusing solely on the traits of individuals without understanding and addressing how the culture of the organization

In summary: no matter how "intellectually ready" an individual may be, the organizational culture and supervisory influences that surround that individual will always exert tremendous impact on the expression of those traits and characteristics. The synthesis of all three of these levels must therefore be achieved for an effective strategy of intellectual readiness to be developed. In this sense, intellectual readiness may best be considered an organizational goal, rather than an individual one.

For the US Navy to become an "intellectually ready" force—one that attracts and retains top technological talent, and one whose personnel are mentally and psychologically prepared to do battle in the face of uncertain and complex situations—the entire organization, from bottom to top, must align to this goal. Efforts to stimulate innovation, such as sending mid-career leaders to courses where they learn about innovation, for example, are fruitless unless those individuals are afforded an environment that rewards innovation and embraces change. Arguably, many such innovators already exist in the Navy, but in order for them to be empowered to make significant change, the constraints that govern their behavior (for example, how they are led, instructed, evaluated and promoted) will need to be aligned with the goal of innovation, rather than current existing goals and strategies.

Intellectual readiness can be conceived as existing at three distinct levels: the individual or team level, made up of individuals and units of people; the supervisory level, which is made up of senior enlisted and senior officer levels and equivalent civilian staff; and the organizational level, which is made up of high level staffs, such as type commanders, operational commanders, combatant commanders, etc. In this sense, I describe a kind of "innovation ecosystem"--an environment that is aligned with the goal of growing new ideas; enabling change; promoting adaptability and response to dynamic environments.

An effective innovative ecosystem is one where the environment itself must foster innovation by creating the conditions where thinking big ideas are encouraged—environments where processes are not sacred; where change is expected and welcomed. Similarly, middle management must embrace and embody these characteristics, and realize their role as enablers of change, not gatekeepers or barriers to change. And lastly, the organization at the highest levels must also support the goal of intellectual readiness through evaluation and promotion policies that reward innovative and creative thinking and experimentation; that allow failure (e.g., learning) to occur; and that embrace a diversity of ideas. Such "generative organizations" have been demonstrated to produce not only better and more innovative ideas, but are also more likely to weather significant market upheavals, and are more capable of pivoting their business models to new markets when necessary (Westrum 2004,Scoblic 2020).

And there are plenty of historical examples that support the innovation ecosystem view as well. If we consider famous examples of rapid innovation in the Navy—the Sidewinder missile development at China Lake in the 1950s, the Polaris submarine-launched nuclear missile in 1960, the strategic studies group of the 1980s and its generation of innovative maritime strategies that led the Navy through the Cold War—we can see that those accomplishments were not merely the result of innovative individuals. They were a combination of unique cadres of supportive supervisors and remarkable work environments where experimenting with new ideas, "tinkering" and "failing fast" were common and accepted. These are the conditions that keep people satisfied and interested in their work. These are the conditions that breed innovation.

1.5. Conclusion

To summarize the preceding sections, the introduction of new technologies produce ripple effects with sometimes unintended consequences. Principles that govern the use of new technologies are most commonly inherited and passed down from earlier analogs, or constrained through top-down influences. These principles govern how the technology will be effectively used--their practices. Organizations that promote a kind of "tinkering" culture, or ones that allow or enable exploration and experimentation tend to promote better practices that yield better outcomes, whereas limited experimentation or constrained use tend to create poorer outcomes. The dividends of new technological investment, therefore, are a function of how that technology is approached, which is largely determined by the organization more than it is by individual operators.

Similarly, systems that integrate humans in ways that embrace their unique strengths (non-linear thinking, creativity, abstract reasoning, context-awareness, intuition) instead of perceiving them as weaknesses to be controlled are more resilient to dynamic fluctuations in the environment. Organizations that limit the opportunity for bottom-up innovation likewise produce unintended consequences on their people's ability to rapidly adapt and appropriately respond to unexpected changes in the environment; such systems are highly brittle to environmental fluctuations, and condition their people in ways that are counterproductive to responding to uncertainty and complexity.

For the US Navy to become an "intellectually ready" force—one that attracts and retains top technological talent, and one whose personnel are mentally and psychologically prepared to do battle in the face of uncertain and complex situations—the entire organization, from bottom to top, must align to the goal of intellectual readiness. Such an innovation ecosystem consists of professionals who are trained and equipped; supervisors who facilitate and encourage; and administrators who enable and promote in ways that reinforce an intellectually ready and adaptive force.

Although the prevalence of discussion has thus far focused on the role of the organization, the foundation of an innovation ecosystem is a well-prepared and trained people. Hence, this project was commissioned to define what it means to be intellectually ready by developing an individual model of intellectual readiness. The process and methodology through which this model was developed and later validated will be discussed in detail in the preceding sections.

Model Development

"There's a long tradition of having a "fix it yourself" mentality when it comes to hardware in the Navy; wrench turning and tinkering is a time-honored approach. But with software, we can't touch a thing."

- Navy O3, serving at sea

"My job isn't to care about what you are good at. My job is to fill billets. "

- Navy O4 detailer, NAVPERS

2. Development of an Individual Model of Intellectual Readiness

2.1. Developing an individual model of Intellectual Readiness

Just as Navy ships must attain conditions of material readiness, which indicate their ability to respond when called upon, individual units and personnel must also maintain various forms of readiness as well, including physical readiness, and medical readiness. The concept of intellectual readiness might therefore be considered the mental and psychological equivalent of a person's physical readiness. Personality characteristics such as agreeableness or determination or "grit," and attributes such as a person's ability to interpret instructions and to learn new materials all play a role in military personnel being ready to do combat (Fletcher 2013) and thus contribute to overall combat effectiveness.

The purpose of developing an individual model of intellectual readiness is to provide the grounds for a personnel selection program, and to guide the foundation for training. The personality features or characteristics that are identified in the model would become either educational initiatives, or constructs on which to base selection criteria for hiring or recruiting purposes (e.g., getting people with the right skills and characteristics into the right jobs). So it is vitally important that the characteristics that go into making a model are both related to the concept (e.g., have good construct validity), and are something that can be measured and attained, and ideally something that can be trained.

In an effort to define intellectual readiness, many groups over the past 20 years have built models (e.g., see the literature on Cognitive Readiness, Morrison 2002) which attempt to define the concept using aggregates of popular psychological concepts from the literature (Crameri 2019). This method, while valid and acceptable, has its limitations. Such an approach is highly susceptible to bias by the researcher who must determine what psychological concepts should be included and why. They are free to choose any rationale they like, but ultimately the decision of what is included and not is up to the researcher themselves, who may or may not know much about the domain they are working in (i.e., in this case, the US Navy). Models that result from this approach may be defensible in an academic sense, but if the intention is to build something that will be used in the real world and serve as the foundation for future decisions, that model should have strong ecological validity and be grounded in formal theory.

To define intellectual readiness, therefore, I chose an approach that would ensure that both the concept and the model would be developed, not by me, but by the people the model describes. I accomplished this through an approach called grounded theory.

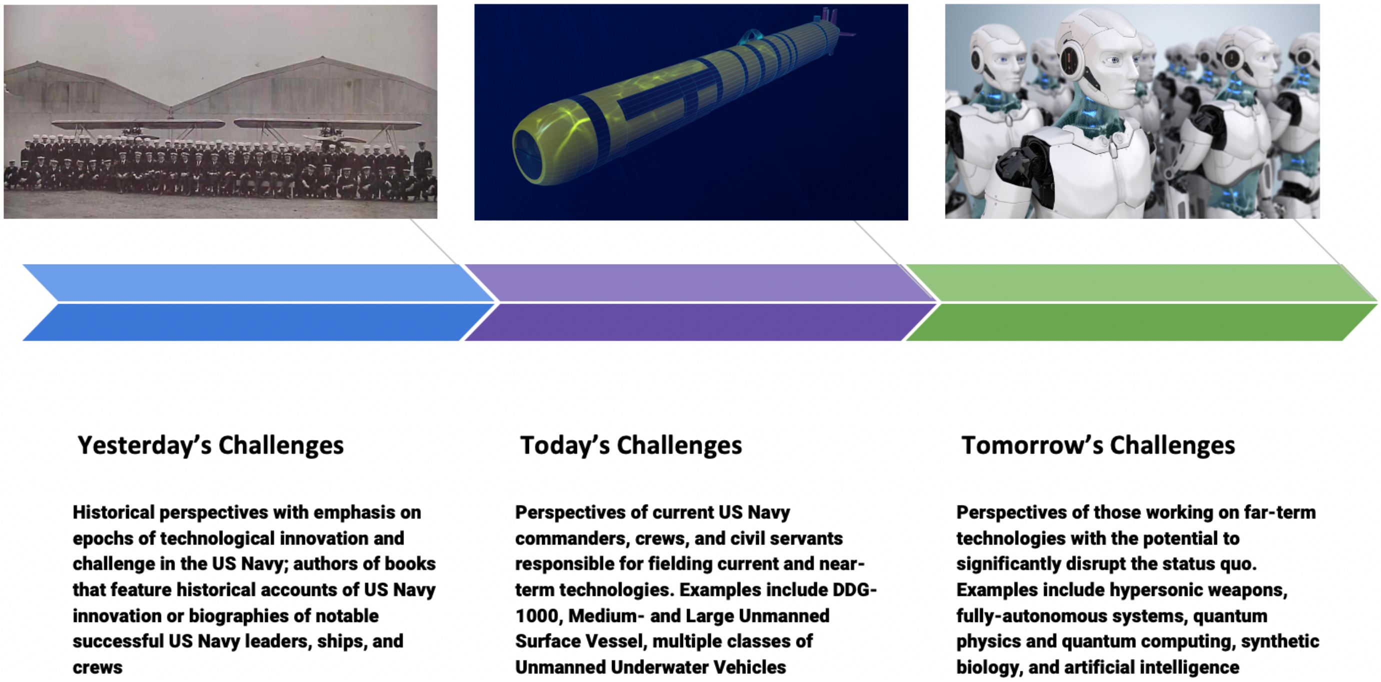
Grounded theory is a research method that develops hypotheses from the analysis of data, rather than from speculation or deduction. This is an example of an inductive approach to hypothesis generation, as opposed to the hypothetico-deductive approach that is more common in research (Goldkuhl 2010,Dey 1999). In grounded theory, rather than beginning with the hypothesis "intellectual readiness is..." and then proceeding to collect data to support that hypothesis, instead I began by asking "what is intellectual readiness?" and proceeded to gather data that would enable me to answer the research question.

2.1.1. SOURCES OF DATA

To choose my sources I was motivated by three main goals. The first goal was to ensure that the voices of those who this model would represent (e.g., the individual operators) were included and prioritized. Too often is research done in the name of the "war fighter," but does not include said war fighter in the research in any meaningful way. Speculating about the needs and wants of US service members from afar does them little service, and commonly results in recommendations or technologies that are poorly fit for their intended audience. Hence, I spent considerable effort in tracking down and interviewing active duty Navy personnel across all ranks and warfare domains, serving at shore and at sea.

Another goal of my approach was to ensure that the characteristics developed represented those that had strong ecological validity. In other words, I wanted to consult directly with experts in emerging technologies; with people who are intimately and expertly familiar with these technologies, rather than to speculate about those technologies from afar, or merely read about them. Hence, I sought out said experts from across the technological spectrum in both the government and private sectors.

Lastly, in preparation for this project I read through two decades' worth of government-funded research on "cognitive readiness." This not only familiarized me with what had previously been written on the topic, but also made me keenly aware of the tendency for people to forget. The US Navy as an organization has faced the challenge of responding to emerging threats and developing new technologies multiple times over its 246 year history. Additionally, innovation in the US Navy is an immensely popular



topic with a robust and active community of authors, historians, and enthusiasts. As an amature student of history myself, I frequently avail myself of historical precedents or anecdotes in order to support my arguments or illustrate my ideas. Hence, I sought to include historical perspectives into the model development effort in the hopes that earlier lessons might not have to be repeated.

I therefore recruited participants from three broad groups: 1) historians and authors who have studied and written about innovation in the Navy, or who have studied and written about organizational culture in the context of innovation; 2) Navy operators and leaders who are currently serving on active duty in units that are fielding new and experimental technologies, such as DDG-1000, unmanned underwater, aerial, surface, and ground vehicles; and Columbia class submarine; 3) scientists and engineers who specialize in emerging technologies such as quantum, artificial intelligence, synthetic biology, autonomous systems, hypersonic weapons, and cyber. These three groups represent three distinct perspectives; one historical, one based in the current operating context, and one based in the future. These three perspectives were deliberately chosen to ensure that an individual model of intellectual readiness for emerging technologies would be developed holistically, and would be based in equal parts on historical precedent, current needs, and future speculation.

2.1.2. INTERVIEW FORMAT

To gather data I used a formal interview (also known as a structured interview) technique. Interviews were conducted either in person, via web conferencing, or via satellite phone (for individuals serving aboard active US naval vessels). Most interviews lasted an hour, and many were conducted in multiple parts covering many hours of discussion.

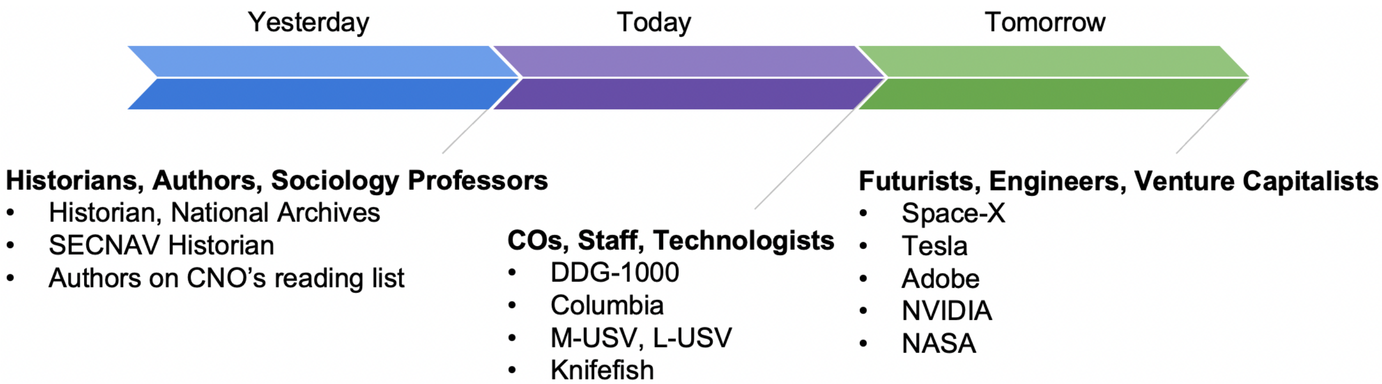
To begin each interview, I first described a future scenario to ground the participants and orientate them to the same perspective:

Employment opportunities from high-tech private sector industries like civilian space, self-driving cars, smart electrical grids, and the continued thriving of internet-based services have created a marketplace for young, techno-savvy entrepreneurs and workers who can make above-average wages with benefits straight out of high school or college. New work structures maximize telework, and allow people to work on flexible work contracts that do not require long-term commitments. The average high school graduate has more opportunities for education and travel, and the promise of sustained earnings than any generation before them. Meanwhile, growing concerns over large-scale conflicts with near-peer adversaries are on the headlines daily. Artificial intelligence and autonomous systems are everywhere, used by both friendly and adversary forces. New technologies never before seen are coming on line, and how these technologies may change the nature of warfare is not immediately clear.

I then asked the following questions to begin:

What kinds of personality traits, characteristics, and cognitive *abilities will sailors of tomorrow need to successfully operate in uncertain environments filled with complex technologies? What attributes or characteristics will be most valuable in the techno-centric scenario described above?*

From there, interviews would evolve depending on the answers provided to the questions above. In each interview, I made every effort to ask for specific examples of attributes or characteristics, and asked for citable sources wherever possible.



Over the course of seven months I conducted interviews with a total of 49 individuals, resulting in over 100 hours of transcripts. Through these interviews I garnered significant insights into the characteristics of successful innovators, both past and present; discussed what it means to be "ready" to respond to adversity, uncertainty, and complexity; and began to get a sense of the complex relationship between an organization and its people in times of challenge and uncertainty.

I spoke with historians from places like the National Museum of the Marine Corps; the Navy Heritage and History Command; the Office of the Secretary of the Navy, and heard many historical biographies of innovative leaders, such as Admirals Halsey, Nimitz, Rickover, and Sims. I spoke with authors of historical books who shared with me examples of successful and unsuccessful leaders and organizations with colorful stories and rich anecdotes. I spoke with scientists and engineers on the bleeding edge of technology today from places like the National Quantum Initiative; Adobe; NVIDIA; DARPA; and NASA. These conversations largely speculated on what future sailors will need to be like to cope with an increasingly complex and constantly changing technological battle space.

And most importantly I spoke with as many US Navy sailors as I could. I spoke with individuals across all ranks to ensure I was not biasing one particular perspective, and I went out of my way to interview sailors serving in active units. I spoke with Surface Warfare Officers, Engineering Duty Officers, Aviators, Explosive Ordnance Disposal technicians, and Submariners. In more than one circumstance, these conversations were had over a patchy satellite phone line at 2:00am because of the time zone differences of where the ship was operating. From these conversations I heard about the current state of innovation in the US Navy; how the Navy culture treats new ideas, and how talent management is approached across a variety of warfighting domains (e.g., the fitting of individuals and their skills to jobs, and criteria used to determine whether or not they are promoted).

Interviews were allowed to range according to each participant's frame of reference, but efforts were always made to identify what characteristics or attributes that were central to what these people considered to be the concept of intellectual readiness.

2.1.3. LITERATURE REVIEW

To complement the data I gathered through formal interviews, I also conducted a detailed literature review of domains such as business innovation, organizational culture, team science, psychological assessment, and cognitive and behavioral psychology. These domains were chosen because they were the most salient to the developing concept of intellectual readiness, and were most likely to yield empirical support for the traits or characteristics that best enable someone to respond to uncertainty and manage complexity.

As was noted above, previous efforts to create models of intellectual readiness were criticized for their lack of empirical grounding. To constrain this literature review and ensure the applicability of its results to the concept of intellectual readiness, I specifically focused on A) situations or scenarios that involve organizations or people having to cope with surprise or unexpected change, such as a person needing to retrain for a new career after a life-altering accident; or an organization who may have to pivot their established products or processes in order to remain competitive; B) personality constructs related to the adoption and efficient use of new technologies; or C) psychological attributes relating some construct of intelligence or aptitude to interactions with complex technologies.

Next I sought to cross-reference each attribute described through formal interviews with those found in the scientific literature. Attributes that were mentioned by interviewees but were not found in the scientific literature, either because they lacked empirical definitions or were not empirically supported by scientific fact, were omitted. In some cases attributes that shared significant features were reduced and combined into one overarching construct (e.g., numeracy and mathematical aptitude were combined to create the attribute computational literacy). A table of attributes was then developed to reduce the number of attributes to produce a reasonably sized model, and the frequency with which each attribute was mentioned or supported in the literature determined its final eligibility in the model.

The result of these steps was a definition of intellectual readiness as expressed by study participants. This definition reflects the historical perspective, the current operational perspective, and the future perspective. Intellectual readiness is defined in this project as:

The cognitive and psychological preparedness necessary to sustain performance and respond appropriately in the face of uncertain and complex situations

In addition to this definition I developed an individual model of intellectual readiness that comprises 12 attributes. These attributes originate directly from interviews with experts, and were supported in the scientific literature as being empirically valid, testable, and in most cases trainable.

The individual attributes of the model are described in the following section.

Model Development By The Numbers

NUMBER OF PARTICIPANTS INTERVIEWED

Technical Experts, government & civilian

15

Active Duty Navy Personnel

17

Historians and Authors

17

TOTAL

49

"Most people in the Navy are expected to play within the rules of the game. The current system punishes people for considering alternative rules of the game."

"WE [THE GOVERNMENT SECTOR] SIMPLY CANNOT COMPETE WITH THE PRIVATE SECTOR. I CANNOT HIRE ENGINEERS AND TECHNICIANS FAST ENOUGH, AND THE TURNOVER IS REMARKABLE."

"LOTS OF COMPANIES TRY TO KILL SMALL INNOVATIVE GROUPS LIKE SKUNK WORKS, EVEN WHEN THEY ARE ESSENTIAL TO THEIR KEY PROJECTS. WHY? BECAUSE SKUNK WORKS IS CINDERELLA. EVERYONE HATES CINDERELLA BECAUSE CINDERELLA MAKES EVERYONE ELSE LOOK BAD."

"STANDARD DOD PROCEDURE REQUIRES SYSTEMS LIKE THE AIR OPERATIONS CENTER (AOC) SOFTWARE TO BE COMPETITIVELY BID, AND FOR THE WINNING CONTRACTOR TO DESIGN, BUILD, CERTIFY, AND TEST THE ENTIRE SYSTEM BEFORE DELIVERING IT TO USERS—AND THEN TO GO THROUGH THE ENTIRE PROCESS AGAIN EACH TIME ANY APPRECIABLE AMOUNT OF CODE NEEDED TO BE CHANGED. THAT'S IN PART WHY THE AOC SOFTWARE HAD BEEN IN USE MORE OR LESS UNCHANGED SINCE THE 1990S. THEY USE A WHITE BOARD, STICKIES, MAGNETS, AND EXCEL SPREADSHEETS TO DETERMINE THE MISSIONS FOR THE DAY, FIGURED OUT WHAT TARGETS NEEDED TO BE HIT, AND HOW MUCH FUEL WAS NEEDED, WHO NEEDED THE FUEL, AND WHEN THEY NEEDED IT... IT WAS AN EIGHT- OR NINE-HOUR PROCESS [FOR THREE OR MORE PEOPLE] TO TRY AND FIGURE OUT ALL THE INS AND OUTS. IT WAS LIKE A TETRIS GAME OF BLOCKS AND PUCKS."

"MOST OF HISTORY DOES NOT DEMONSTRATE BIG TECHNOLOGICAL ASYNCHRONY. MOST COMBATANTS TEND TO BE RELATIVELY SIMILAR TO ONE ANOTHER IN TERMS OF TECHNOLOGY, WHICH MEANS THAT ALL THE OTHER FACTORS BECOME MUCH MORE IMPORTANT DECIDING FACTORS. HISTORY IS PRETTY CLEAR ON THIS: TECHNOLOGY IS NOT A WAR-WINNER."

3. Individual Attributes of Intellectual Readiness

The 12 Factors of Intellectual Readiness were developed through a grounded theory approach and validated using principal components analysis. The individual characteristics below represent the constituent traits, characteristics and attributes that both individuals and organizations must possess to respond appropriately to dynamic uncertainty, both in acute as well as long-term time scales. Each attribute is briefly described below.

ANTICIPATORY THINKING

A cognitive skill enabling the analysis of system states, anticipation of outcomes, and forecasting of future events; the deliberate exploration and analysis of relevant alternative system states

COMPUTATIONAL FLUENCY

A quantitative skill that permits the comprehension and manipulation of numerical information; an ability to conduct basic mathematical operations fluently

FAR TRANSFER

The extent to which a person can solve problems in domains for which one has no formal training by using previously learned knowledge from other domains

EMOTION REGULATION

An ability to regulate one's emotions in response to adverse events through the willful adjustment or control of one's thoughts

INTELLECTUAL CURIOSITY

A characteristic of ranging, divergent thinking that seeks depth in understanding; one who exhibits an eagerness to expand one's knowledge, and a willingness to accept new ideas

MECHANICAL COMPREHENSION

The capacity to apply simple mechanical and physical principles to solve problems using visual-spatial reasoning and an understanding of cause-effect relationships

METACOGNITION

The internal mechanism used to plan, monitor, and assess one's understanding and performance; an awareness of the way one thinks

COGNITIVE ASYCHRONY

Having an independent point of view that frequently differs from others; a strong, independent personality

PATTERN RECOGNITION

The degree to which a person demonstrates a systematic way of thinking; one who demonstrates proficiency at procedural tasks and recognizing patterns

RESILIENCE

An ability to adjust to or recover from illness, adversity, or disruptive events and setbacks

SITUATION AWARENESS

The perception of environmental elements and events with respect to time or space, the comprehension of their meaning, and the projection of their future status

TEAMWORK

A willingness and ability to cooperate with others to achieve common goals by subordinating personal prominence to the efficiency of the whole

3.1. Anticipatory Thinking

In the after-events of the attacks on the Twin Towers on 9-11, the 9-11 Commission's final report concluded that the attacks on the world trade center and pentagon were caused chiefly by a "failure of imagination." Throughout the report, specific mention was made about a unique skill that some people possess which allows them to speculate about potential futures. The 9-11 report cited the need for this characteristic to become more commonplace amongst our military and defense sectors. Accordingly, the Central Intelligence Agency, along with several other government agencies involved in defense and intelligence, set about to formally define this characteristic in order to begin training it. Thus the concept of "anticipatory thinking" was born.

Anticipatory thinking is often defined as "the deliberate, divergent consideration of relevant possible futures" (Geden 2019). The characteristic of anticipatory thinking is often referred to as "mental time travel," which describes a person's ability to explore and analyze future events that have not yet occurred through some systematic way of speculating about the future.

Anticipatory thinking is when a person anticipates future system states in order to identify key indicators that may lead to those future states. By speculating about the future, one can discover key signs or events that could prove critical to preventing those future events. Studies of neurology indicate that the act of imagining future events, and remembering past events (both real and imagined) share common underlying neurological mechanisms (Botzung 2008, Schacter 2008, Schacter 2007, Okuda 2003). This suggests that the act of anticipatory thinking may trigger the same neural pathways used in problem solving, which is the theoretical basis on which the importance of anticipatory thinking rests.

People who are good at practicing this skill are less likely to be caught off guard, and are more likely to develop contingency plans to ward off potential futures that are not ideal (Amos-Binks 2022, Thomson 2020). Accordingly, this attribute may be useful in both short and long-term planning. For example, anticipatory thinking is arguably the most important mental process of playing games such as Chess (Burgoyne 2016, Moxley 2012). But anticipatory thinking can also be critical for long-term readiness--the kind of preparedness necessary to avoid technological surprise in future conflicts; the sort of readiness the US Navy seeks to attain.

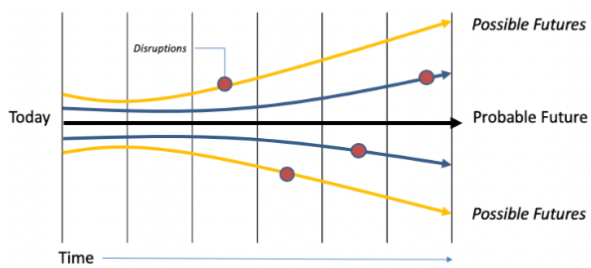


Figure 3: Anticipatory thinking is the act of imagining future possibilities in order to identify warning signs, and using those activities to plan for possible futures.

3.2. Computational Fluency

An intelligent system is any system that can represent data, reason about it by examining patterns and relationships, and interpret that data to arrive at a desired output (Ye 1995). A commonly distinctive feature of intelligent systems is prediction. A prediction is a probability of an action or outcome, typically derived from structural equations whose variables have been shown to have associative characteristics (Cokely 2012).

Intelligent systems synthesize data via sensors, and process that data according to programmed algorithms in order to arrive at a conclusion (prediction). The Patriot missile defense system, famous for its service in the first Iraq war and used by dozens of allied countries around the world, is an example of an intelligent system used by the US Military. The AEGIS weapon system is another prime example, and is currently installed on 22 cruisers and 62 destroyers (Janes.com 2021).

The rise of intelligent systems and the infusion of artificial intelligence into mainstream society has resulted in a significant need for users and operators of said systems to be computationally literate. Understanding the input-to-output relationships between data and computer-aided decisions requires a level of familiarity and comfort with mathematics. Understanding the safe operating boundaries, when system outputs should and should not be trusted, recognizing conditions that could create system errors, and even understanding system-generated explanations all involve some mention of mathematical concepts such as distribution of data, central tendency, skewness, etc.

Related to the concept of basic numeracy, computational fluency refers to a basic familiarity with mathematical operations in order to understand relationships between data points, compare risks, and be capable of accurately interpreting decimal representations, proportions, and fractions. (Ghazal 2014). People who are computationally fluent are more likely to correctly interpret system-generated predictions and recommendations, and are more likely to demonstrate appropriate levels of trust with those systems (Sheridan 2019).

3.3. Far Transfer

Learning is commonly understood to occur at different levels, with each level corresponding to a learner's ability to use new information in some meaningful way. Bloom's taxonomy (Bloom 1957) is one of the most cited examples, and describes how learners may progress into deeper, more significant understanding with materials, from rote memorization through the creation of new knowledge. When a learner is able to use newly acquired knowledge to solve familiar problems, this is commonly known in educational parlance as "near transfer." It is "near" because the problem set is near to, or closely resembles, the learned material. When learners are able to solve problems in areas they have never received formal training for, on the other hand, this is known as "far transfer."

A classic example of near transfer learning might be a learner recognizing that they can use the Pythagorean Theorem from high school geometry to determine if two fence lines are square across a wide area. They merely need to measure two existing sides and compare those sides to a third. An example of far transfer learning might be a learner understanding the principles and physics of water pressure, and using that knowledge to fix a vapor-locked hydraulic pump on a tractor engine. Although the learner has never been formally trained to work on tractor engines, by understanding the similarities and commonalities between water pressure and industrial hydraulics, the learner was able to solve the problem.

Far transfer represents a significant depth of learning, well beyond rote memorization or other passive learning whereby learners merely commit material to memory in order to do a job or pass a test. Far transfer represents the full assimilation of knowledge, and is the underlying goal of higher education. Unfortunately, however, efforts to standardize learning, especially in very large organizations with high volumes of students often necessitate practices which reinforce superficial levels of learning.

Although there is evidence of individual differences in determining whether some students learn far transfer or not, in general, far transfer is a learnable behavior, and is therefore something that can be trained (Barnett 2002). Training that requires learners to interact with and use knowledge in some meaningful way (e.g., through projects, or using new knowledge to solve problems) reinforces the importance of far transfer, and encourages learners to engage with new material in a more substantial manner than merely seeking to memorize it (Sala 2019).

3.4. Emotion Regulation

Keeping a cool head in the face of immediate danger is universally agreed upon as critical to successful warfighting. Historical anecdotes and Medal of Honor citations are filled with mention of people's legendary stoicism in the face of mortal danger. But emotion regulation is not only useful on the battlefield. Fear is an especially dangerous emotion because of its immediate effects on decision making (Hartley 2012, Aronowitz 2010, Ferrer 2022, Strojny 2020), which can manifest itself in slower, and poorer longer-term decisions.

Leaders who fail to recognize their own fears often lead organizations into situations that are difficult to recover from and that produce lower performance than leaders who actively acknowledge and avoid fear-based decision making (Ahmadi 2016, Kirkpatrick 2010).

Emotion regulation is also critical to learning. Being able to persist through challenging material, and maintain clarity of thought even when struggling to comprehend new concepts is a skill that many students lack when first attending college (Spann 2019). Thankfully, emotion regulation can be taught, and is sometimes learned through experience (Maxwell 2019,Pollock 2016).

Whether the person be junior enlisted or a senior commander, the importance of emotion regulation has been reinforced across a wide variety of domains, and is commonly cited as critical to a host of activities related to intellectual readiness, including creative thought (Angela 2022,Stawicki 2022), problem solving (Shadrick 2005), and performance in competitive activities (Bilalić 2009,Burgoyne 2016).

If we return to the definition of intellectual readiness, we can clearly see the central importance of emotion regulation:

> ***The cognitive and psychological preparedness necessary to sustain performance and respond appropriately in the face of uncertain and complex situations.***

The ability to sustain performance and respond appropriately is highly predicated on one's ability to maintain a steady emotional state in the face of stressful and challenging conditions (Moreau 2022).

3.5. Intellectual Curiosity

The characteristic of being naturally curious may not appear at first blush to be linked to successful military innovation. After all, the US military, and indeed all military organizations that feature well-defined hierarchies, operate on the principle of following orders from above. Intellectual curiosity often expresses itself through the act of questioning, of asking "why" or "why not." People who are intellectually curious may be interpreted as troublemakers, often because of their tendency to question the status quo. Others may openly criticize the establishment, suggesting alternatives to improve processes. Such questioning in some military communities (most notably infantry units, but also surface and sub-surface Navy units) is often interpreted as insubordination, which can be severely punished.

Unfortunately, this misinterpretation is problematic. The core motivation behind such questioning is not out of spite to superior officers or from lack of discipline. The core motivation of intellectual curiosity is to understand. Much research has been devoted to intellectual curiosity in recent decades, especially its role in innovation (Orona 2021,Stumm 2011). The desire to know and understand is the primary precondition for learning, without which learning is passive and may not occur (Khan 2019). But intellectual curiosity also creates a condition that is considered necessary for innovation to occur--the readiness to accept new ideas(Stumm 2011).

Studies routinely confirm that people who are more likely to ask "why" and "why not" or who engage in divergent ways of thinking have schemas that are more welcoming to new ideas than people who don't (Mussel 2010). Openness to new ideas or experiences remains a hallmark of creative personalities, and is highly correlated with other personality features of innovators, such as high imagination, curiosity, sensitivity, and original thinking (Feist 1998).

In pursuit of the aforementioned definition of intellectual readiness, having people who can readily update their thinking, rather than those who persist with old, outdated ways of thinking--especially in the face of new information, new opportunities, or new challenges, is optimal. While military discipline is vital in a professional military, and insubordination cannot be tolerated, shutting down those who may observe better ways of doing things, or whose ideas may be the key to true innovation is inefficient and costly in terms of human capital, and is contrary to the military's goals of retention and talent management. While intellectual curiosity may not itself be a trainable attribute, there is considerable opportunity to teach those who exhibit the characteristics of intellectual curiosity how to do so within the boundaries of a professional military organization. This may involve teaching concepts such as tact, timing, or even delayed gratification (i.e., rather than asking questions in front of the entire division at morning quarters, finding a more ideal time to ask questions).

Similarly, it may not be realistic to attempt to make all leaders more "intellectually curious," but teaching leaders to tolerate or even to embrace intellectually curious sailors may contribute significantly to the discovery of new ideas and ways of doing things, and therefore contribute to a more intellectually ready force.

3.6. Mechanical Comprehension

Modern efforts to define and measure human intelligence have consumed scientists and psychologists for more than 100 years. Surrogate measures of intelligence, such as the ability to solve puzzles, often serve as useful predictors of not only general intelligence, but also of specific performance outcomes. Mechanical comprehension is one such surrogate.

Mechanical comprehension is an umbrella term that refers to a person's ability to comprehend relationships in complex machines and other cause-effect relationships, for example, the ability to mentally visualize and manipulate objects, such as the turning of gears and their connection to pulleys and levers. Aside from the benefits of being "good with tools" or being able to disassemble and reassemble complex mechanical parts, mechanical comprehension also correlates with a tremendous amount of performance outcomes and associated traits, and is predictive of a surprisingly wide array of performance outcomes across a multitude of different domains (Johnson 2004). Mechanical comprehension was one of the first surrogate tests included on military aptitude tests, and remains a significant part of aptitude testing today (North 1977,Meitinger 2009).

Although the digital revolution has largely reduced the amount of physical interaction that sailors have with their machines today, the concepts behind mechanical comprehension are just as applicable to software engineering as they are to hardware. For this reason, mechanical comprehension remains a highly salient attribute today: whether for troubleshooting new systems, discovering new ways of doing things, or engineering innovative new systems.

3.7. Metacognition

Metacognition is the process of thinking about how one thinks (Peña-Ayala 2014). It is an awareness of the processes that for many go unnoticed. Much of our mind relies on automation to cope with the vast amounts of data the brain has to process every second of consciousness. Because of this automation, many decisions and strategies can be adopted without any thought, especially in the context of learning or interacting with new and novel ideas. Individuals who a more metacognitively aware are those who bring learning strategies and patterns of thought into consciousness, and reflect on their meaning, purpose, and suitability towards one's goals.

Aside from learning, however, metacognition is most commonly thought of as a core component to creative thinking. The concept "think outside of the box" refers to metacognition. The box, in this metaphor, represents the artificial boundaries people often place on their thinking, especially when trying to solve new problems they have never seen before. Take for example, the classic "nine dot" test in Figure 2 below.

It is common to see the arrangement of nine dots in a square grid and expect that the solution of lines much remain within that grid (e.g., the "box" from the metaphor). To solve the puzzle, however, one must recognize the possibility of drawing lines that extend beyond the grid, and only then do the solutions become apparent. Metacognition has been studied in a wide variety of domains and found to be predictive of higher performance in teams (Jia 2019), and central to critical thinking and problem solving (Fruehwald 2013).

3.8. Cognitive Asynchrony

Preparedness and capacity to respond to uncertainty are the core features behind the concept of intellectual readiness. Because new technologies open the door to new potentials that are often not fully understood or explored, it is frequently up to early users willing to experiment with these technologies to discover new use cases, potential vulnerabilities, and innovative ways that these technologies can trigger tactical advantages.

My discussions with scientists and leaders in various emerging technological fields about the necessary characteristics of sailors of tomorrow evolved surprisingly often into discussions about the characteristics of creative and innovative people. When asked to describe the ideal operator of tomorrow's intelligent systems, most people answered predictably: people who had good mechanical aptitude; good with math; careful decision makers; even-keeled emotionally; good learners, etc. But when asked to describe what characteristics are necessary to innovate or create something new, answers were strikingly different. Terms such as quirky, unusual, asynchronous, unconventional, creative, colorful, and avant garde were mentioned.

Because the concept of intellectual readiness is rooted in the ability to respond to novelty, which is itself rooted in a sort of creative thinking and problem solving, it became evident that creativity itself may be a necessary attribute to consider for inclusion.

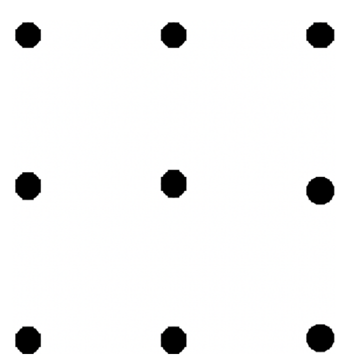


Figure 4: The classic 9-dot test. Instructions are to connect all nine dots using only three or four straight lines, without raising your pencil or pen from the page.

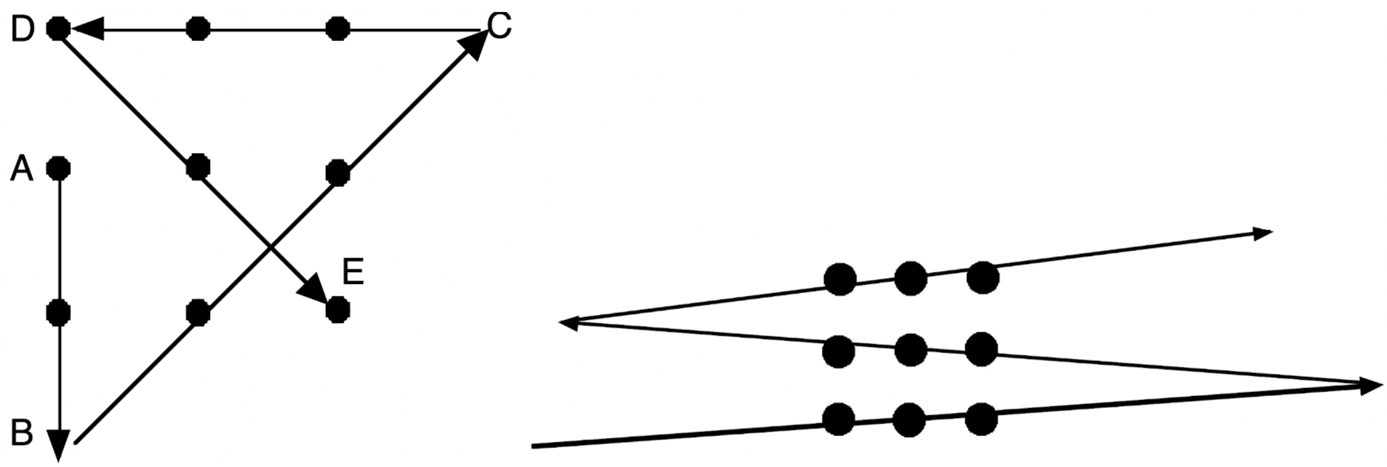


Figure 5: Two potential solutions to the nine dot puzzle. In both cases, the only way to solve the puzzle is to recognize that there are no boundaries to the puzzels. Becoming aware of how you are bounding or limiting your thinking is the central concept of metacognition.

Unfortunately, however, creativity is such a broad topic, with many definitions and manifestations, I feared using it would lead to the same kind of watered down one-size-fits-all solutions that previous reports such as this have produced. After careful probing of interviewees for clarification, and cross-referencing their testimony with literature on creativity and innovative people, the concept of cognitive asynchrony was submitted.

Cognitive asynchrony describes a unique way of thinking that is out of step, or asynchronous, with one's peer group. Divergent thinking is another synonymous term. In this case, the differences in patterns of thought are not lesser-than or greater-than others', but rather they are different, sometimes radically different, than established ways of thinking.

When asked to describe their top-most performers, or the people who had contributed the most to innovative ideas in their organization, current US Navy personnel often replied using terms such as "odd ducks," "trouble makers," "outliers," and "ones who are different." Indeed, studies of the personalities of serious innovators have revealed that many are often non-conformists, often seen as troublemakers, and are significantly different from their peer group.

A meta-analysis of 29 separate studies of personality and scientific creativity, for example, revealed that the feature that clearly differentiated scientists and creative people from non-scientists or creative people was achievement via independence (Feist 1998), which is defined by strong, independent drive to excel at one's work and a clear preference for freedom and individual initiative. The descriptions of creative individuals from these 29 different studies of the personalities of creative people yielded surprising results that parallel my findings from various interviews with Navy operators about innovative people in their units. To quote directly from the study:

"The most striking thing about this pattern of results is how low artists are on the socialization-control scales... Such a strong pattern of results suggests personalities that are conflicted, impulsive, nonconformist, rule-doubting, skeptical, fiercely independent, and not concerned with obligations or duties. The only... scales on which artists were higher than norms were [flexibility] and [self-acceptance], suggesting that although they are conflicted and rebellious, artists seek change, were easily bored, and yet see themselves as talented and worthy people." (Feist 1998, p. 298)

It is not surprising that people who are capable of paradigm-changing ideas may be somewhat different from their peers. A mind that can conceive of things that do not currently exist must draw inspiration from someplace. It stands to reason that this place of inspiration stems from a unique way of seeing the world, and independent patterns of thought and perception (e.g., cognitive asychrony).

Obviously a unified fighting force cannot be made up of highly non-conforming people. The US Military strives to achieve conformity as part of its principal personnel strategy, which suggests that there is a fundamental conflict between the personalities of serious innovators, and the qualities of being a professional military officer or enlisted member. But as was illustrated earlier in the introduction, what is perceived as weakness or vulnerability, under some circumstances is actually a strength and advantage. People who can only think as they are told, or whose patterns of thought derive largely from their peer group are more likely to suffer from group think and be stymied by truly challenging circumstances. In those circumstances, a unique perspective may be the most valuable element. Learning how to manage creative "rebels" or innovative "troublemakers" may very well be a skill that needs to be taught to supervisors, as well as developing a new perspective that sees cognitive asynchronous people as assets and not liabilities.

3.9. Pattern Recognition

The ability to recognize an emerging threat, trend, or vulnerability is an important skill in combat as much as it is in business. Pattern recognition has long been considered an important attribute for a number of domains, and has been firmly evaluated as a contributing factor to general intelligence through the empirical literature (Johnson 2004).

The attribute of pattern recognition is specifically describing the characteristic of identifying patterns from noise--often patterns that have never been seen before, and that may be quite subtle. For example, aberrations in sonar signals that correspond to seemingly meaningless events in the timeline may reveal the existence of a new silent tracking device that is emitting a sonar "shutter" when perturbed by passing wakes. This discovery would only be possible if the correlation of the aberrations to the events on a timeline were noticed, and then were interpreted as something worth exploring. This would be an example of pattern recognition combining with intellectual curiosity. The two attributes complement each other in a way that leads to new discovery. An emphasis on developing good pattern recognition by itself, however, can lead to unconscious bias.

Cognitive scientists have long demonstrated that humans do not typically engage in deliberate, methodical decision making, but rather, most decision-making strategies are predominantly those that make efficient use of heuristics, or mental shortcuts (Vorm 2018,McNeil 2009,Klein 2009,Porter 2009,Sirota 2021). For heuristics to be useful, however, they must be a good fit within a decision environment. Individuals who continue to rely on heuristics that are a poor fit for the environment will develop inaccurate working models of a situation or process, which will in turn lead to biased and inappropriate decision making.

So it is important to keep in mind that the kind of pattern recognition ideal for intellectual readiness is distinct from a more general preference for, or reliance on, known patterns. An over-reliance on known patterns is more likely to result in oversimplification (Feist 1998,Lang 2019,Lombrozo 2006), which often results in misdiagnosis and response to unknown or unexpected events (Sebok 2016).

3.10. Resilience

Resilience, also commonly known as "grit" refers to a mindset of determination, and the mental practice of deliberately controlling one's thoughts (Flood 2022). The US Department of Defense has widely embraced the concept of psychological resilience, due in part to research over two decades on its importance in resisting long-term effects of stress, and favorable contributions towards well being and recovery from traumatic events (Flood 2022,Vötter 2019,Kanapeckaitė 2022,Sohail 2021,Ureña 2021).

Responding proactively to adversity; bouncing back from setbacks; learning from mistakes; and persevering through difficult circumstances are all features of a person with strong psychological resilience. These are highly important features in the context of intellectual readiness because the concept specifically involves situations that are challenging and require persistence.

3.11. Situation Awareness

Situation awareness is defined as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley 1995, p. 36). The construct, as first described in the context of aviation human factors engineering, has been successfully applied to a broad number of high-risk domains to aid in understanding of human information processing. Situation awareness is described in three levels: perception, decision, and action. These three levels describe the integration of human sensory organs with the decision making components of the mind.

A person whose perception is finely tuned to recognize slight changes or irregularities in an environment is one who is less likely to be caught off guard or be surprised. A person who can recognize the significance of these changes is one who is more likely to adapt or prepare for future events. A person who can incorporate this information in order to form a plan of action, and successfully execute that action is one who is ideally equipped to respond to uncertain and unpredictable events. Throughout the interviewing phases of this project, operators repeatedly mentioned the importance of having a "keen eye" on the horizon, and described characteristics such as people who "always have a good understanding of the whole situation."

Situation awareness is something that all human beings have, but to varying degrees. There have been a wide variety of effective training strategies developed to improve a person's situation awareness, most notably through the US Federal Aviation Administration (Bolstad 2010,Bolstad 2002,Endsley 2000,Muehlethaler 2016). Better situation awareness has been associated with fewer accidents (Shariff 2017), better decision making (Dodge 2021), and most salient to the concept of intellectual readiness: more appropriate responses to unexpected events (Pritchett 2014,Vorm 2020,Sebok 2016).

3.12. Teamwork

Teamwork is central to the accomplishment of most goals. Being able to prioritize the needs of others; the ability to communicate well and in a manner that contributes to team cohesiveness; and being able to take orders and be subordinate to others are all key to this attribute.

Throughout the interviewing phase of this project, the attributes that comprise teamwork were frequently mentioned as being central to successful innovations, both in historical contexts, as well as current operational examples. Again, this is not surprising. The US military is first and foremost a team of teams, and therefore all training reinforces the values that contribute to team cohesiveness and esprit de corps.

The characteristics of highly functioning teams are also very salient to discussions of intellectual readiness because for hundreds or even thousands of years, the decisive factor of whether battles are won or lost often come down to how well individuals work together towards a common goal (Burke 2020).

Just what comprises the attribute of "teamwork" is unfortunately somewhat muddled and open to interpretation. There are obvious characteristics that come to mind: communication skills, attention skills, coordination skills; but there are other characteristics that are harder to define and measure, such as loyalty, devotion, and willingness to be subordinate to others. Because of this, the attribute may mean different things to different people. Nevertheless, participants **in this study were unambiguous about the importance of teamwork to the concept of intellectual readiness, and hence it is included in this model.**

Figure 6: The individual model of Intellectual Readiness, developed for this project, defines 12 attributes considered important to manage technological complexity and respond to uncertainty.

Model Validation

"Many organizations have no clue as to the mechanisms of their own success... they also don't have any clue about where they are leaking talent or money."

- Author and Professor of Organizational Culture

" We are hemhoraging talent at an alarming rate."

- Navy O6, The Pentagon

4. Validation of the Individual Model of Intellectual Readiness

4.1. Model Validation

The development of an individual model of intellectual readiness is an important first step in defining and characterizing the goal. But such a model is itself incomplete without some effort to validate it. Model validation examines how well the model "fits," or describes, the data. It is often said in the scientific community that "all models are wrong; some are useful." For this project, "model fit" would best be described as how well each of the attributes describes or characterizes the concept of intellectual readiness, as decided by experts and stakeholders.

Because the concept of intellectual readiness has only recently been defined and has yet to be codified in any formal way, there is still much opportunity to refine and update it. Participants in this validation study help accomplish this by telling me (through their data) which of the attributes I developed for this model fit what they think intellectual readiness is or should be, and which of those attributes do not fit. In essence, we are testing the model of intellectual readiness developed for this project against their individual conceptual model to see how well my model fits. With a large enough sample of experts and stakeholders, we can therefore reasonably infer from the data whether the 12 factors developed earlier have captured what it means to be intellectually ready.

4.2. Interpretation of Data

The first level of analysis I conducted was to examine consensus and disagreement across the entire sample pool of data. This provides a broad measure of how well the 12 factors fit with participants' conceptualization of intellectual readiness.

In order to analyze these data, I first standardized all scores using Pearson's product-moment correlation (r). Standardization is necessary because in order to meaningfully compare statements to each other, there must be an established unit of measurement. Thus, standardized scores (Z scores) are created which convert absolute scores into relative scores, which permit the analysis of each statement's placement and ranking as it corresponds to the overall sample mean. The further away from the sample mean in either direction (positive or negative) indicates that statement's relative strength, which in this study indicates its degree of fit or appropriateness to the concept of intellectual readiness, as determined by our participants.

4.2.1. ANALYSIS OF THE SAMPLE WHOLE

Examining the distribution of statements from across the entire participant pool revealed clear preferences and priorities for certain attributes. Metacognition, far transfer and situation awareness were all ranked positively or in positions of higher priority by all participants, while mechanical comprehension, computational literacy, and cognitive asynchrony were all ranked lowest priority across the sample.

To understand why some attributes were consistently ranked high or low, I examined the reasons given in response to prompts at the end of sorting, as described above. Brief discussion of the results for each attribute are provided below.

4.2.1.1. METACOGNITION

Metacognition was ranked as the highest priority attribute amongst the participants in this study. People who can adjust their thinking strategies when necessary; who consciously evaluate the way they think and choose appropriate strategies; and who are consciously aware of their own cognitive processes have wide consensus amongst the participants in this study. When asked to provide reasons for why they ranked this attribute higher than all other attributes, participants provided the following:

"Given the ambiguous nature of the problem stated facing an uncertain and complex situation, flexible thinking backed up by a broad knowledge base is more likely to be applicable to a random problem. If the problem statement is narrowed then a more specialized approach would be more likely to be effective."

"In a dynamic environment a person must be willing to realize what they need to unlearn as much as they need to learn and adjust accordingly."

"Adaptivity is one of the most important characteristics of the human intellect. Being able to adjust one's way of thinking in the face of a changing environment and circumstances is critical for intellectual readiness. Without that ability most other traits could become moot once an individual faces new challenges and situations and previous thinking paradigms are no longer applicable."

"I think the most important aspect of being prepared intellectually to respond to new and unknown situations is adaptability:

Metacognition Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who can adjust their thinking strategies when necessary	3	5	3	4	0.078
A person who evaluates the way they think and chooses appropriate decision making strategies	2	1	0	1	0.131
One who is consciously aware of their own cognitive processes	0	2	-3	0	0.587

Table 3: Statements comprising the attribute Metacognition. Z Score variance ranges from very low to moderately high, which indicates the factor's salience varies depending on the group's perspective.

knowing that previous thinking strategies may not be well-suited to the problem expecting that your initial strategy to approaching a complex problem is likely to fail and being able to learn and adapt from those failures."

From these statements it is obvious that metacognition was widely interpreted as a kind of mental flexibility, which is ultimately considered most valuable by these participants in response to the context of problems that are unanticipated or previously unknown. Metacognition is a trainable attribute, and successful programs have been developed and used, many by the DoD, to develop this attribute.

4.2.1.2. FAR TRANSFER

Far transfer is the ability for a person to use knowledge gained in one domain to solve problems in another domain where they have never been formally trained. Participants in this study ranked far transfer as the second-most important attribute, indicating its prominence in the construct of intellectual readiness. Almost universal consensus was reached in the rankings of this attribute. So little variance between participants suggests that this attribute is widely considered relative to the concept of intellectual readiness.

When asked to provide reasoning for why this attribute was ranked higher than other attributes, participants provided the following:

"Problems can be solved indirectly sometimes. A chemical process can be interpreted as a quantum computing operation if the inputs are set up correctly"

"We work in a multi-domain world. Lots of effort has been put into building interfaces that display information from all over battle-spaces or other environments. To be able to recognize where knowledge from one domain can help in another saves time and effort for all. Also speeds up the training for this person when being introduced to new technologies since they are being fielded much quicker than previously. An overall more useful sailor that can be plugged into more roles."

"New technologies and ideas always build in some ways on

Far Transfer Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who has a solid understanding of a broad range of topics	1	0	0	0	0.001
A person who can take knowledge from one domain, and apply it to another	4	2	2	3	0.105
A person who sees connections between different ideas or problems easily, often where others don't	4	2	2	3	0.311

Table 4: Statements comprising the attribute Far Transfer. Z Score variance is very low, indicating a high degree of agreement across all three groups.

Situation Awareness Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who perceives situations quickly and understands the downstream effects	3	3	0	2	0.282
One who sees the chessboard from both sides; one who grasps the whole situation	2	0	-1	0	0.295
Being able to rapidly assess situations and project the consequences of actions into the future	5	1	1	2	0.554

Table 5: Statements comprising the attribute Situation Awareness. Z score variance for this factor indicates moderate disagreement across all groups.

previous ones. Transferring knowledge about one domain into another is in my view the biggest piece of succeeding in a new domain."

"Having in-depth knowledge of a single topic is only useful in situation when that topic is important. Understanding how that in-depth knowledge is or isn't applicable to other situations makes it more broadly useful. With finite sized teams it's impossible to have an in-depth knowledge of everything."

"Sparks fly when things just barely intersect"

Achieving far transfer is arguably the goal of all education and training, from elementary school and beyond. While some students are more naturally inclined to learn in a way that is transferable to new situations, teaching techniques and curriculum development have proven to be highly effective at improving far transfer across a wide variety of educational domains(Sala 2019,Barnett 2002). HOW the US Navy approaches education (e.g., how curriculum is developed and delivered, how educational goals are set and attained) has a greater impact on whether or not sailors will be intellectually ready than any individual differences in personality or natural aptitudes.

4.2.1.3. SITUATION AWARENESS

The attribute of situation awareness, not surprisingly, is quite salient to the concept of intellectual readiness, and was ranked highly amongst all participants. People who demonstrate the ability to rapidly assess situations and project their consequences into the future; who perceive situations quickly and understand their meaning; who can "see the chessboard from both sides" are favored by all participants in this study. Situation awareness and its importance in strategic decision making and safety has been studied for many decades and remains a strong component of intellectual readiness. When asked to provide reasons for why

Teamwork Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who willingly acts as a team member	-2	1	1	0	0.309
One who has good listening skills, and who communicates well with others	0	4	2	2	0.433
A person who gets along well with others and is able to work well in diverse groups of people	-2	3	0	0	0.57

Table 6: Statements comprising the attribute Teamwork. Z Score variance is significant, indicating that this factor was controversial amongst our groups.

Intellectual Curiosity Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who asks questions frequently	0	-1	3	1	0.454
A person with a strong desire to explore the unknown and push the limits of how things are done	0	-1	3	1	0.498
A person who has a strong desire to know and understand things	1	1	5	2	0.613

Table 7: Statements comprising the attribute Intellectual Curiosity. Z score variance for this factor indicates moderate disagreement across all groups.

participants ranked this attribute above others, they provided the following:

"Given the definition of intellectual readiness provided and assuming their rapid assessments and projected consequences are accurate (or accurate enough) this person is most prepared to sustain performance and respond appropriately in uncertain or complex situations."

"Being able to accurately assess a problem is good; being able to correctly project the solution into the future is great (highly valuable in software development); and being able to do both rapidly is about as good as it gets in my field if you ask me."

"There is a relationship between correlation and causation. The ability to recognize the correlation of situations or information and determine causation to predict the outcome of a course of action is critical."

"Given that any artificial intelligence will be procedurally-driven, the ability to predict the consequences of actions will give someone the leg up in terms of both deploying and combatting artificial intelligence-driven weapons."

Situation awareness is a trainable attribute, and many government organizations, most notably the federal aviation administration, have developed and utilized situation awareness training for their employees.

4.2.1.4. TEAMWORK

Teamwork is a central goal of all DoD training, and is key to a professional military organization. It is not surprising, therefore, that wide consensus emerged around the importance of teamwork as an attribute of intellectual readiness. Participants across all groups ranked all attribute statements of teamwork high in priority, with the highest Z score being 2, and the lowest being 0 (which is the statistical mean in our distribution). When asked to provide reasoning for why teamwork was ranked so favorably, participants provided the following:

"If you can't convey intent or understanding you'll be mis-interpreted or ignored. Communication is key to developing understanding and moving forward."

"Future tech and AI capabilities will far outpace individual cognitive capacity. Humans will have to be excellent at cooperation and forming cooperative relations/networks to maximize impacts from AI. I emphasized the skills/comms part of this because when/where we choose to form teams will still be important (i.e. some teams may not work so individuals shouldn't over-emphasize 'team player' attributes if they don't maximize greater mission or end state)."

"The "concept" will be developed by more than one single individual. It's the collaboration of the group to determine what intellectual readiness is. For a group to function well, communication is one of the key factors of getting to the solution."

Teamwork is a trainable skill, and is already central to most training in the DoD. These results merely reinforce its prominence in the concept of intellectual readiness.

4.2.1.5. INTELLECTUAL CURIOSITY

Participants in this study broadly agreed that people who express a strong desire to know and understand concepts; who ask questions frequently; and who desire to explore the unknown possess important attributes that contribute to the concept of intellectual readiness. These attributes bespeak a spirit of exploration, which has historically been associated with the sea services, and are widely favored in domains of discovery, such as science, engi-

Figure 7: Composite sort, representing the average of the entire sample pool. This assortment represents the average of all participant's opinions about how well each statement describes the concept of Intellectual Readiness. Statements towards the right are ranked more important, while statements on the left are ranked less important. Statements in the middle represent the mean, which is Zero. Standard deviation is 2.5. Statements are color coded according to which attribute they represent.

neering, technology development, etc.

When asked to provide reasoning about their rankings of intellectual curiosity, participants provided the following:

“A person who is inquisitive and curious will tend to have a more open mind about a situation."

“Intellectual readiness requires comfort in the face of uncertain and complex situations. A person faced with such challenges that actually enjoys it and "plays" with new ideas and ways to think about things implies they can remain innovative in difficult situations and not reactive. They won't react to an issue, they will play with it, figure out what it really means and come up with new ways to address it."

“To me, intellectual readiness means you aren't afraid to explore new ideas, and you are willing to look at things from different perspectives or do analysis with varying approaches."

“Regardless of background, learning always starts with sincere curiosity. I believe that someone who is intellectually ready for a world filled with AI and autonomous systems is a person who is willing to learn about these technologies and adapt to the changes they bring."

Whether or not curiosity is a learnable or trainable attribute is somewhat in dispute. There are some techniques that can en-

Emotion Regulation Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who is comfortable with ambiguity and uncertainty	1	1	1	1	0.017
One who is self-aware of their emotions and can control their emotions	-3	3	1	0	0.797
One who maintains a steady state emotionally, especially when stressed	-1	4	-2	0	0.867

Table 8: Statements comprising the attribute Emotion Regulation. Z Score variance is mostly high, indicating a high degree of disagreement across all three groups.

courage curiosity, but the primary consensus amongst academics is that curiosity is largely inherent to a person's personality.

One important factor to note regarding intellectual curiosity is its relationship with one's environment. It has long been noted that the ability to think is predicated on the perceived ability to act. In other words, individuals who believe that they will be able to make changes in their environment are more likely to think of creative solutions or have open minds. Even the most naturally curious individuals, on the other hand, will cease to seek novel solutions to problems or search for alternatives in environments where new ideas are not welcomed, or asking questions and looking for new ways of doing things are discouraged or punished. It is important, therefore, to keep in mind that the attributes in this model must also be supported by the supervisory and organizational levels for those attributes to produce intended benefits. It would be inefficient to expend valuable resources training individuals to be more intellectually curious, only to see their curiosity curtailed by a system that is overly bureaucratic and hostile to new ideas.

4.2.1.6. EMOTION REGULATION

On average, participants ranked the attribute of emotion regulation favorably in this study. A person who is comfortable with ambiguity and uncertainty; who maintains a steady state; and who is self-aware of their emotions is one who is more likely to remain focused and objective in the face of adversity and challenge. Hence, participants widely agreed that emotion regulation was an important attribute to intellectual readiness.

When asked to provide reasoning for their rankings of this attribute, participants provided the following:

"There is a lot of uncertainty and ambiguity in life about the future and in the pursuit of knowledge. It is best to learn how to cope with this and become comfortable with it."

"You cannot get flustered when faced with novel, uncertain, and ambiguous situations, even if they last a long time. People struggle with this and will try to take immediate steps to remove uncertainty even when they are not the best option in the long term. Being intellectually ready requires being able to sit comfortably and patiently with ambiguity while searching or waiting for the right opportunity to act. Put simply, a certain but bad outcome must not be preferable to working to reduce ambiguity and uncertainty or simply waiting for the fog to clear. "

"I chose this because as we reach new stages of learning there will be more answers than questions and it's important for people who are intellectually ready to be able to handle this idea of not knowing everything."

Emotion regulation is something that has been successfully trained across a wide variety of domains, but most commonly is the context of anger management, psychological well-being, etc. Its relationship to decision making is less commonly associated. This is an area of importance for consideration because intellectual readiness is primarily concerned with responding appropriately (e.g., making good decisions) and sustaining performance in the face of difficult, complex, uncertain situations. Training individuals emotion regulation techniques for the benefit of decision making in uncertainty, therefore, should be a high priority for future training development.

4.2.1.7. PATTERN RECOGNITION

Being able to recognize patterns is an important feature in general, and is often associated with general intelligence (Sheridan 2019,Johnson 2004). But having a preference for known patterns, or artificially trying to fit new situations to existing patterns (known as anchoring bias) is detrimental to good decision making, especially in situations that are new. Participants in this study were mixed on the importance of pattern recognition. Of the three

Pattern Recognition Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who demonstrates a systematic way of thinking; good at procedural tasks	-1	0	-2	-1	0.138
A person who does well solving complex puzzles	2	-2	0	0	0.445
One who quickly recognizes patterns	3	2	-2	1	0.666

Table 9: Statements comprising the attribute Pattern Recognition. Significant Z score variance indicates this factor created broad disagreement amongst the groups.

attribute statements, the highest Z score was 1, and the lowest was -1 (standard deviation for our sample was 2.5). To understand the reason behind this variance, we can examine participants' reasoning, which they provided when they ranked pattern recognition either highest or lowest in their sorting.

Positive

“I'm surmising that simpler autonomous systems will use algorithms that result in predictable decisions and it would be advantageous to recognize that pattern to defeat an adversary's systems and aid or supplement friendly systems. I also think sailors who learn to predict the decisions of friendly autonomous systems will be more comfortable relying on them."

“Thinking about a complex system involves thinking about nonlinearity because a complex system requires understanding not just constituent parts and connections but also feedback loops. Few can think in such a manner. Most think merely linearly and in terms of complicated systems."

“This is important because people with this trait will take their time and document their findings."

Negative

“Humans are built to recognize patterns quickly. Machines are even better at this than we are. We need humans to interpret the patterns and respond accordingly. Patterns, though potentially useful, do not establish causality and can be purely random. This doesn't imply good solutions in the face of uncertainty. It implies knee-jerk reactions and lots of chasing down blue herons."

“”Complex puzzles" appeal to a small subset of the population, and these are the individuals that will be good at them. But there are many that do not enjoy (and therefore do not do well) complex puzzles and have innovative ideas. There are many individuals with creative thinking who imagine new solutions to problems

Anticipatory Thinking Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who can engage in mental time travel to simulate what the future might look like	1	-1	-1	0	0.113
A person who likes to play with new ideas and can think about things in new ways	2	0	4	2	0.331
A person who asks "what if" more than "what is"	-1	-2	2	0	0.46

Table 10: Statements comprising the attribute Anticipatory Thinking. Z Score variance is moderate, indicating a disagreement regarding this factor across the groups.

deemed previously unsolvable - and they hate puzzles."

"Systematic thinking is good except when it's not: when the problem is new or there is limited information then established systems can break down or lead to wrong conclusions."

From these statements it becomes clear that there are aspects to the attribute of pattern recognition that appear important and valuable, and others that appear to be a vulnerability. During the model development portion of this project, pattern recognition was often mentioned as a skill that contributed to strategic success. For example, being able to recognize the relationship between ship movements and certain transmissions made it possible to decode enemy encryptions during WWII (Jones 1993). Recognizing patterns is also a common strategy in games such as chess, and has been found to be a key factor to developing effective strategies to win against an opponent (Burgoyne 2016,Moxley 2012). But while these represent strengths, there remains a strong tendency for humans to reduce new situations and attempt to fit them into existing schemas or mental models (Hendricks 2018,Mercier 2011). In this sense, metacognition—one who is aware of how they are thinking, and who can deliberately adjust their thinking when necessary—would serve as an antidote to potential bias. Thus, teaching pattern recognition would only be valuable towards the goal of intellectual readiness if it was done with the above caveats.

4.2.1.8. ANTICIPATORY THINKING

Recalling from the earlier section, anticipatory thinking has been defined as the "deliberate, divergent consideration of relevant possible futures" (Geden 2019). Anticipatory thinking was ranked favorably amongst most participants, with Z scores ranging from 0 to 2. Its importance to critical decision making and future planning has been well established, thanks in part to frequent mention of this attribute through prominent scientific articles, as well as government reports such as the 9/11 commission's report (Norton 2004).

When asked to provide reasoning for their rankings, participants provided the following:

"This ability is essential to enabling several of the other ideals. Without enjoying new ideas a person isn't likely to deviate from the norm if given a choice. Likewise an inability to perceive things in new ways will hinder the ability to work with a teammate's ideas or understand the benefits of new ideas."

"This trait demonstrates someone always curious and willing to explore ways to improve a method/project to be forward thinking and not stuck in old ways of thinking. "

"Open-minded to try something unexpected when conventional ways do not work"

In attempting to describe the characteristics of anticipatory thinking, it is possible that some participants may have misinterpreted the attribute statements as belonging to intellectual curiosity; statements between the two appear to have significant overlap. Therefore, it would be beneficial to revisit this concept in future studies and see if it can in fact be parsed from intellectual curiosity. Nevertheless, the attribute statements which the participants sorted for this study were ranked favorably by most participants as being important to the concept, which indicate it has reasonable validity as a construct for intellectual curiosity.

4.2.1.9. RESILIENCE

Mental resilience has gained a prominence in DoD training recently, thanks in part to an attempt to stem the rising rate of suicide amongst uniformed personnel. Being able to persist through adversity, and maintaining a strong positive attitude is important

Resilience Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who remains committed even when against tremendous setbacks	-2	0	1	0	0.171
A person who believes they can achieve whatever they set their mind to	-4	-1	0	-2	0.563
A person who sees challenges as opportunities for growth	-1	0	4	1	0.858

Table 11: Statements comprising the attribute Resilience. Z Score variance is moderate to high, indicating a high degree of disagreement across all three groups.

in difficult situations, as well as in managing everyday life. Resilience was included in this model largely because of the frequency that it is mentioned in relation to critical decision making, dealing with adversity, and managing complexity (Flood 2022,Vötter 2019,Kanapeckaitė 2022,Sohail 2021,Ureña 2021). Historically, many prominent Navy figures have been described by their remarkable resilience. Farragut's "Damn the torpedoes, full speed ahead!" or John Paul Jones' "I have not yet begun to fight" are illustrative of a particular kind of mental resilience in the face of grave danger. But the kind of resilience that is often cited in the literature is less about heroism, and more about maintaining resilience over the long term, especially after stressful events. So its prominence as an attribute of intellectual readiness may be muddled.

Participants in this study ranked resilience with a high amount of variance, with Z scores ranging from 1 to -2. This indicates low reliability as a construct, although this validation study was not intended to formally validate constructs. Rather, this variance amongst the participant sorts indicates that the attribute statements chosen may have been misunderstood, or that the importance of this attribute to intellectual readiness is more controversial than other attributes.

To better understand this variance, participants were asked to explain their reasoning for their rankings of resilience. This is what they said:

Positive:

"I believe that ultimately a growth-based mindset is critical to solving problems of any sort. This concept will carry through to every relevant area of intellectual readiness. If an individual believes that they will not be able to solve the problem then the rest of the skills do not matter. Contrarily viewing every challenge as an opportunity will afford a person a tremendous advantage and provide an environment where the rest of the characteristics can be employed."

"Scientific challenges are essentially a mystery that if solved will provide new ways of approaching problems - essentially broadening our scientific horizons. Personal challenges allow us to see life from different perspectives which broadens our horizons. Without challenges there would be no need for innovation nor solutions. Challenges are essential to change. Often the easiest or most obvious solution to a challenge (if it exists) is not useful because it has bad "side effects."

"Every situation comes with its own set of hurdles and setbacks. The key to success is to remain steadfast against such challenges, use them as learning experiences and come out of them as an improved and more knowledgeable person."

"From what I've encountered, people who see challenges as a way to grow as a person are more willing to take on difficult tasks, create new more productive systems of doing things and are generally more willing to put themselves in uncomfortable circumstances because they know the potential reward greatly outweighs any short term negatives. These are the people that further an organization."

"Determination and belief are critical to intellectual readiness as you will not be easily deterred."

Negative:

"While this person's confidence is admirable it doesn't inherently convey anything about whether or not they'd be able to perform in an uncertain and/or complex situation."

"A person like this may have a hard time actually achieving real goals because of the infeasibility of being able to achieve whatever they set their mind to"

"This is antithetical to intellectual readiness. Simply believing you can do something has no bearing on whether you can do it. On the contrary it could potentially promote delusional optimism on what's possible."

"This sort of person is dangerous because they believe that they individually are responsible for success. They may also be extraordinarily afraid of failure and take unnecessary risks to solve an unsolvable problem, placing solving the problem ahead of all other priorities. That sort of inflexibility is the opposite of intellectual readiness."

By examining the negative sentiments expressed above, it appears that some of the attribute statements, particularly "a person who believes they can achieve whatever they set their mind to" may have been misinterpreted as confidence (or overconfidence) by some participants. Despite these findings, the concept of resilience remains an important feature of much of today's military training, and is a high priority to the DoD (DoD 2020). The association of this attribute to the concept of intellectual readiness, however, may not be particularly strong, and may therefore be removed from future iterations of this model.

4.2.1.10. MECHANICAL COMPREHENSION

Mechanical comprehension was ranked very low by the majority of participants in this study. It was included in the model

Mechanical Comprehension Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who understands how the parts of a system works together, like engines or electricity	1	-2	-1	-1	0.214
A person who likes to tinker with things, taking them apart and putting them back together	-1	-3	1	-1	0.466
A person who can interpret and manipulate visual information, like being able to mentally rotate objects and shift visual perspectives	0	-1	-4	-2	0.545

Table 12: Statements comprising the attribute Mechanical Comprehension. Z Score variance is very low, indicating a high degree of agreement across all three groups.

of intellectual readiness because its long-standing prominence as being predictive of overall intelligence, and because it has been a core competency of a number of technical jobs in the Navy for more than 100 years (Geden 2019,Crandall 2018). The attribute's low rankings by participants suggest that it does not clearly fit the description of intellectual readiness. To further understand the reasoning of these rankings, participants were invited to explain their reasoning. This is what they said:

"Although this is a useful skill, this sort of isolated skill can sometimes inhibit seeing the big picture at the expense of the details."

"This can be very useful but I object to it being a critical trait as individuals have different talents. I generally rated all "skills" low except for programming."

"I don't think this trait is more related to how well you are at spatial recognition than intellectual acumen."

"This might be a good trait for a specific "job" but I don't think it speaks to whether a person is ready to handle a situation."

"The statement is very precise in its description. It pictures someone who is looking for logical connection, not for understanding and decisions."

Despite these sentiments, there were some who ranked Mechanical Comprehension much higher than others. Examining their reasoning may help to understand why they value this attribute:

"[Tinkering] has been something that the commanding officer has fostered here at UUVRON-1. The more sailors are allowed to tinker and come up with ideas the more we learn about the limitations of the vehicles and what they are capable of. While not every venture produces gold they all have valuable takeaways and lessons to learn about UUV Operations that we can take forward into future projects. It also empowers the sailors to take ownership of the projects which leads to a greater enthusiasm and drive to succeed."

The attribute statement "a person who likes to tinker with things, taking them apart and putting them back together" may have been confused with intellectual curiosity in this case. Indeed, tinkering and "fiddling" with machines may be more related to curiosity than to one's technical and mechanical ability, which is what is being described specifically in this attribute. It also appears from participant sentiment above that mechanical comprehension is more of a "skill" and less of an attribute, and hence participants tended to rank this lower than other more cognitive or psychological attributes. As such, the attribute may be removed from future models of intellectual readiness.

4.2.1.11. COGNITIVE ASYNCHRONY

Statements describing the attribute of cognitive asynchrony were ranked very low with almost no variance across all factor groups. This indicates a high degree of agreement that the attribute, as described in these three statements, is not characteristic of or important to the concept of intellectual readiness.

To best understand why this attribute was ranked so low, participants were asked to explain their reasoning for their rankings of resilience. This is what they said:

Cognitive Asynchrony Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who frequently thinks differently than others about things	0	-2	-1	-1	0.052
One who is unconcerned with social norms; a strong, independent personality	-4	-3	-5	-4	0.065
A person with an independent point of view that is frequently very different from their peer group	-2	-3	-3	-3	0.093

Table 13: Statements comprising the attribute Cognitive Asynchrony. Z Score variance is very low, indicating a high degree of agreement across all three groups.

"Intellectual readiness requires teamwork, and for teams to succeed and thrive the team members must maintain and respect a level of social norms for the group."

"This may or may not be helpful. It seems to speak more to personality than intellectual readiness."

"This person could be difficult to work with - always wanting to do their own thing and/or thinking their way is best. Many projects/problems to be solved required group efforts and multidisciplinary skills. Few problems are for example the single scientist Nobel Prize winning research."

"In today's world, every task or activity has to be done as a team. Even day-to-day activities require interaction with technology and gadgets which aren't inert mechanical objects anymore rather intelligent perhaps emotional entities. Independent work may be good up to a certain point in life like school or college education but beyond that someone who is fiercely independent and does not care too much about team work or social norms (e.g. has a low emotional quotient) is unlikely to become a very successful person."

"You need to be aware of social norms to work with a team. An independent personality is always good to possess but without concern for others it will come off as extremely abrasive and the team will suffer."

"While independent thought is certainly important compared to several other traits listed this sounds more like a superfluous personality trait."

These reasons suggest that the attribute of cognitive asynchrony was largely interpreted as being contrary to teamwork, which was ranked much higher in priority. Descriptions of this attribute indicate individuality, and a departure from established norms. These traits can make teamwork difficult under some circumstances, in part because team identity plays a role in a team's cohesiveness (Salas 2005). Describing the attribute using references to a person's personality and its relationship with established norms may have triggered this perception.

Throughout the model development phase of this project, multiple interviews focused on the innovative "troublemakers" and "rebels" in organizations like Skunk Works and the Manhattan Project. Sailors were quick to mention individuals in their units who didn't quite "fit the mold," but who often came through with a unique solution in a pinch. History and current events are replete with examples of creative individuals who are often non-conformist, but who provide visions of the future that sometimes quite literally change the world.

To this sample, however, cognitive asynchrony, as described in this study, was not appealing or appropriate to the concept of intellectual readiness.

4.2.1.12. COMPUTATIONAL LITERACY

The lowest ranked attribute, and also the one with the highest amount of agreement across all groups, was computational literacy. This attribute was ranked extremely low across all groups, which indicates that it is not considered appropriate for or germane to the concept of intellectual readiness. To understand why this attribute was ranked so poorly by our participants, we can examine their reasoning:

"The mechanics of implementation are not critical in intellectual readiness."

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Computational Literacy Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who is naturally comfortable with math	-3	-4	-4	-4	0.035
A person who often thinks and sees things in mathematical relations	-3	-4	-3	-3	0.119
A person who enjoys computer programming and has a knack for using programming languages	-5	-5	-2	-4	0.266

Table 14: Statements comprising the attribute Computational Literacy. Z Score variance is very low, indicating a high degree of agreement across all three groups.

"Programming is too specialized a skill to apply to the generic uncertain and complex situations given; if the situation pertains to programming then programming is an excellent skill to have. If the problem pertains to finding water in the desert or surviving being stranded in a snowbank a flexible approach to problem solving backed up by a broad knowledge base is more applicable."

"Unfortunately while programming is cool, many tools being used by people getting work done have no interface for programming/automation. If you're talking about intellectual readiness in the context of a high-end future conflict, while these traits may be useful specifically to CYBERCOM for all other warfighting areas, although they all touch the Cyber realm, they have no reach into that realm other than the tools they are given. (Often through the long DoD Acquisition process)"

"Not relevant to intellectual readiness. It is a skill."

"Too limited a characteristic to really be important to a more general concept of intellectual readiness."

"Rigidity of thought and internally focused problem solving is not compatible with an AI-enabled environment."

"This is more of a learned skill and is "trainable""

"Computer programming has at best a passing relationship with intellectual readiness. "

"While familiarity with computers and programming may be helpful, they are not necessarily a key skill needed for Navy operators that must quickly interpret loads of information calmly and decide what it means."

"This seems very specific and not as widely beneficial as some of the other traits."

"Computer programming and understanding the nature of programming languages are no doubt important to the fields of AI/ML but screening individuals on the basis of intellectual readiness as defined by competency in one domain runs the risk of turning away a large swath of intellectual talent from other other fields."

Computational literacy was included in this model because of the frequency with which it was mentioned in relation to the growing digitization of technology, and the increasing importance of software over hardware. Computational literacy is thought to be the bedrock of intelligence, as math is often referred to as the "universal language." But as many participants pointed out above, computational literacy is more of a skill, and less of an attribute in their eyes. Although many of the attributes in the individual model could be thought of as skills (e.g., teamwork, pattern recognition, anticipatory thinking, etc), the participants in this study appeared to have adopted the perspective that these traits were largely inherent or genetic, and any trainable skill was therefore not applicable. This was not the intention when the model was developed; rather, all attributes were intended to be traits that could be trained, even though some might have more natural abilities.

Nevertheless, this participant pool unanimously rejected the attribute of computational literacy, as described in this study, as salient to the concept of intellectual readiness.

4.3. Analysis of Factors

So far we have examined the attitudes and priorities of the sample pool as a whole. Doing this has provided some crude insights that indicate goodness of fit for the 12 attributes included in the individual model of intellectual readiness. In so doing, however, we have condensed and compressed many meaningful insights by averaging the attitudes and opinions of the entire sample pool into one.

Next we will explore the data in a more nuanced and granular fashion through factor analysis. Recall from earlier that factor analyzing data reveals patterns of similarity, or shared common variance. In the case of Q-Methodology, this common variance represents the shared attitudes and priorities of clusters of people. Each cluster (known herein as a factor group) is mathematically distinct from one another.

4.3.1. DESCRIPTION OF FACTOR ANALYTIC TECHNIQUE

To accomplish this, I decided against the traditional survey-based approach with regression analysis and instead opted for a factor analytic approach using Q Methodology(Stephenson 1994). Q methodology is a robust technique that permits detailed analyses of the data by analyzing the degree of affinity and contrast that each statement is prioritized in relation to every other statement, as ordered by individual participants. In this approach, participants are provided statements that describe each attribute, and they are asked to rank order these statements from the ones that are highest and most relevant to the concept of intellectual readiness, to lowest and least relevant.

Rather than using a simple rank ordering device (e.g., lowest to highest in order), participants were required to sort each statement into a forced-choice matrix that would only permit one statement per slot, thus sorting each statement in relation to each other statement. Contrary to Likert-based survey methods that permit participants to rank every statement independently (thus often producing results that are polarized, either all very high, or all very low), this technique uses a Gestalt approach to the prioritization that emulates tradeoffs in everyday decisions--there can only be one most important; even if they think many are equally important, they have to order the statements into the matrix, one per slot.

Because of the forced-choice nature of this activity, participants must resolve conflicts in their own prioritization. This means they tend to spend far longer in consideration of their opinions, and think carefully about how they really feel about the issues they are being asked about. Participants using this method commonly spend more than 30 minutes sorting and resorting their statements until they are satisfied with their placement. In contrast to common survey methods, this technique results in participants who tend to be far more engaged and interested in the task of rank ordering their statements, which results in data that is more reliable and meaningful than data collected through traditional survey methods.

After participants completed sorting all statements into the matrix, they were then asked to provide their reasoning for their highest and lowest choice. In an open format, participants were permitted to write down why they thought their highest and lowest ranked attribute was the most and least important. This reasoning will be used later as part of the analysis.

Once all statements are sorted into the matrix, each participant's arrangement of statements (e.g., their "sort") are inputted into an excel spreadsheet with numbers corresponding to the ranking of each of their statements. This permits all participant sorts to be compared with each other using basic correlation. The resulting correlation matrix provides a superficial but valuable measure of affinity that indicates where opinions were shared and where they differed. But this step is only intended to provide the foundation for a more nuanced and detailed exploration of the data, which is developed using factor analysis.

I used the principal components analysis (PCA) method for factor extraction (Conway 2003), which extracted eight initial factors, or clusters of similar opinion about the prioritization and importance of each factor. In other words, each factor represents groups of people whose sorts looked statistically similar to one another, and thus shared a high degree of common variance. Examining these clusters carefully, I tested several possible solutions, ranging from two to eight factor groups, by examining each factor's eigenvalue and total amount of explained variance of each group.

Ultimately I decided upon a three-factor solution because to-

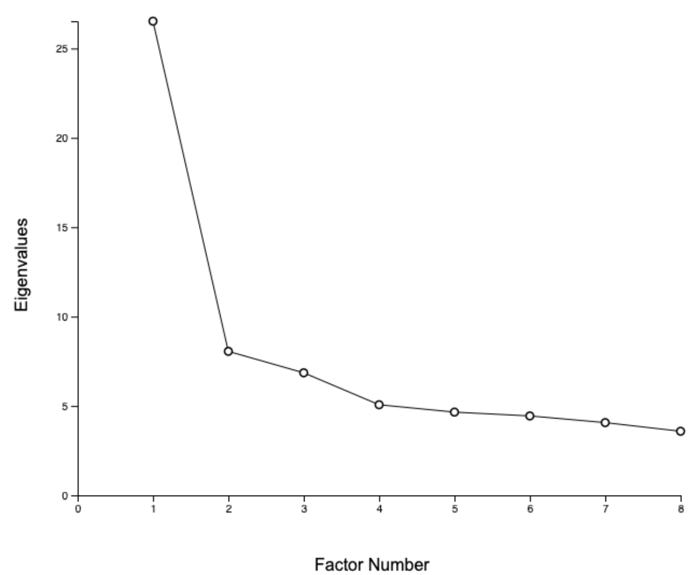


Figure 8: Scree plot, indicating the Eigenvalue for each factor extracted from the data using principal components analysis.

Factor Group Characteristics	Group One	Group Two	Group Three
Number of participants loading in this group	30	32	19
Average Reliability Coefficient	0.80	0.80	0.80
Composite Reliability	0.992	0.992	0.987
Standard Error of factor Z Scores	0.089	0.089	0.114

Table 15: Characteristics of groups extracted using Principal Components Analysis

gether three groups explained the majority of variance (64%) and accounted for the majority of the respondents into a relatively small number of groups that were distinct from one another, yet large enough to permit statistical analysis. 81 participant perspectives were thus accounted for in the resulting factor analysis; 19 participants were dropped because their sorts did not correlate with any of the three discovered factors and were thus treated as outliers.

Using the VARIMAX method to obtain orthogonal rotation of the factors (Akhtar-Danesh 2017), the three factors were rotated. This resulted in three distinct viewpoints with maximized variance between each perspective (see Figure 9). With this accomplished, I began the process of interpreting the data.

In order to interpret the viewpoints of each factor group, I produced a weighted average of each participant's arrangement of questions, then combined each individual's arrangements into one exemplar composite arrangement per factor group. This composite arrangement, or "factor array," was developed for each factor group, then analyzed by examining the relative placement of each attribute statement in relation to each other statement. The results of this analysis are provided below for each factor group. After a description and interpretation of their sorting strategies, I provide a between-groups quantitative comparison analysis.

Factor Group Correlations	Group One	Group Two	Group Three
Group One	1	0.5678	0.3762
Group Two	0.5678	1	0.4484
Group Three	0.3762	0.4484	1

Table 16: Correlations of groups to one another

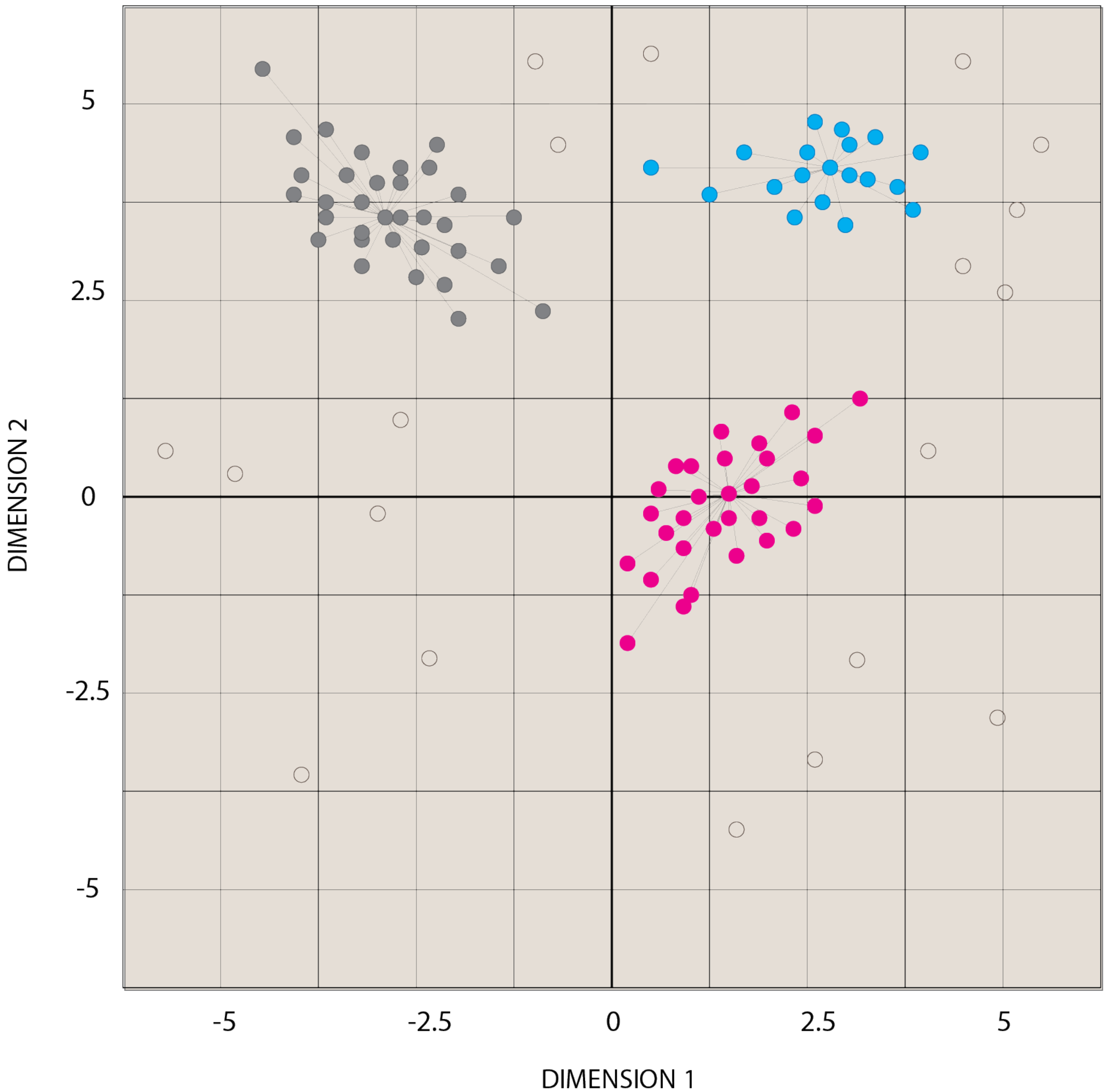
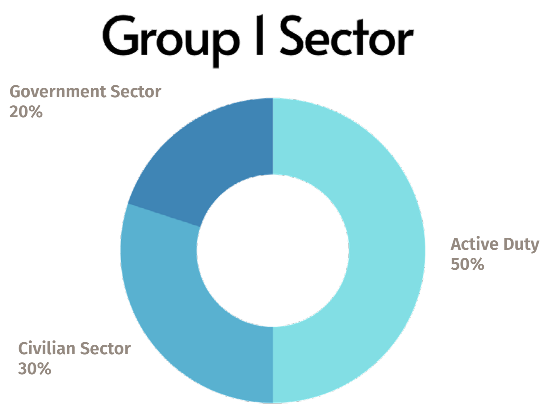
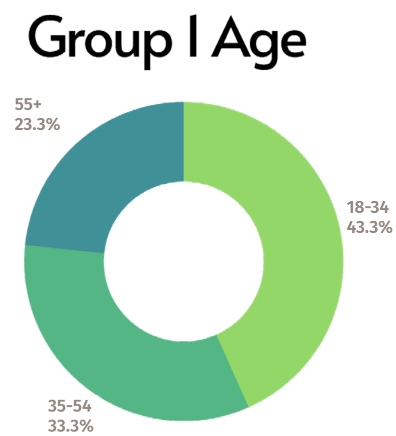
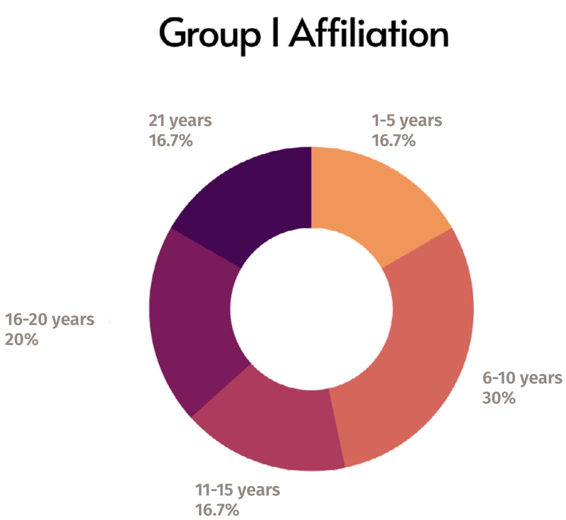


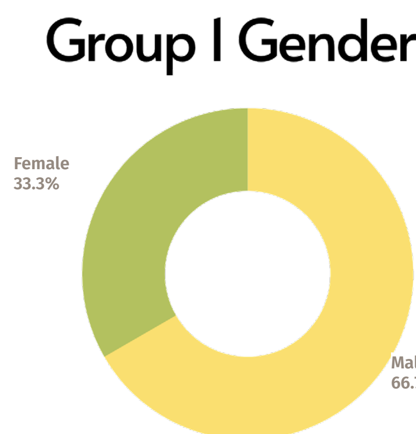
Figure 9: Scatterplot of all participants after factor rotation using VARIMAX method. The resulting clusters are statistically distinct and can be analyzed. 81 participants were included in three extracted factors; the remaining 19 were discarded as outliers.

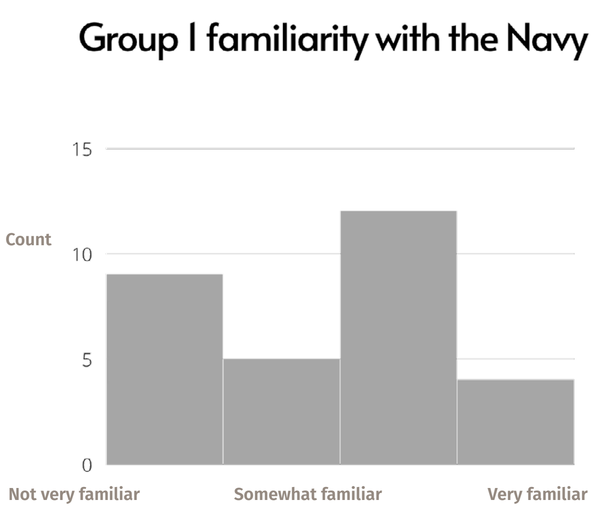
Group One Demographics

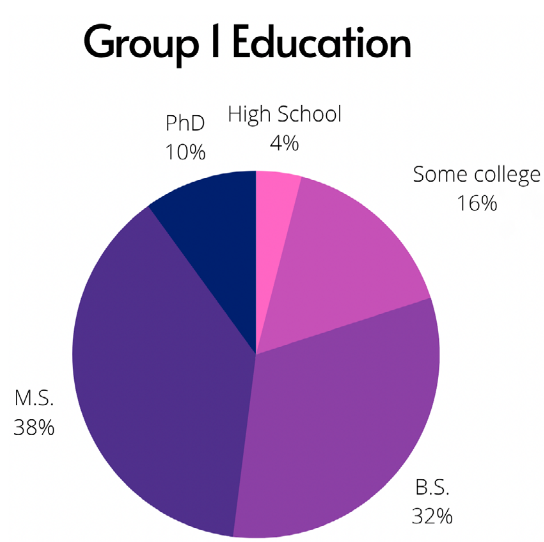












4.3.1.1. FACTOR GROUP ONE

Factor group one was defined by 30 participants and explained 27% of the study variance with an eigenvalue of 27. 67% were male, 47% were older than 34 years old, and 72% had a bachelor's degree or higher. 50% were working in the private sector, 38% were working for the government, and 12.5% were serving on active duty in the US Navy. 53% of group one had been affiliated with the Navy for more than 10 years, and 51% reported moderate or higher familiarity and knowledge of the Navy.

These people favor being able to rapidly assess situations and project the consequences of actions into the future above all other characteristics. They ranked situation awareness and pattern recognition higher than any other group, and interestingly, they were the only group to rank the statement "a person who thinks differently than others about things" favorably. They thought that being able to interpret and manipulate visual information, like being able to mentally rotate objects and shift visual perspectives, and being able to understand how the parts of a system works together were important characteristics to intellectual readiness. This viewpoint contrasted significantly with both groups two and three, who each ranked these statements much lower in their rankings.

This group ranked teamwork and resilience lower than any other group. This contrasts significantly with both groups two and three, who both considered teamwork and resilience very favorably.

Seeing, assessing, perceiving were used to describe intellectual readiness by this group. They seem to prioritize perceptive and analytical characteristics more than other groups, and placed far greater emphasis on these characteristics over those having to do with teamwork. Reading through group one's factor array suggests that they see the ideal of intellectual readiness as being a finely-tuned analytical mind, like a scientist with keen observation and decision making skills.

Group one was predominantly made up of highly educated government employees, and half of them had been affiliated with

Attribute	Highest Ranked Statements	Factor Group 1	Consensus/ Distinguishing	Factor Group 2	Factor Group 3
Situation Awareness	Being able to rapidly assess situations and project the consequences of actions into the future	5	D*	1	1
	Positive statements ranked higher in Factor Group 1 array than in other factor arrays				
Far Transfer	A person who sees connections between different ideas or problems easily where others don't	4	D*	2	2
Far Transfer	A person who can take knowledge from one domain and apply it to another	4	D*	2	2
Situation Awareness	A person who perceives situations quickly and understands the downstream effects	3	D*	3	0
Pattern Recognition	One who quickly recognizes patterns	3	D*	2	-2
Pattern Recognition	One who sees the chessboard from both sides; one who grasps the whole situation	2	D*	0	-1
Metacognition	A person who evaluates the way they think and chooses appropriate decision making strategies	2		1	0
Pattern Recognition	A person who does well solving complex puzzles	2	D*	-2	0
Emotion Regulation	A person who is comfortable with ambiguity and uncertainty	1	C	1	1
Far Transfer	A person who has a solid understanding of a braod range of topics	1	C*	0	0
Mechanical	A person who understands how the parts of a system work together, like engines or electricity	1	D*	-2	-1
Anticipatory Thinking	A person who can engage in mental time travel to simulate what the future might look like	1	D*	-1	-1
Mechanical	A person who can interpret and manipulate visual information, like being able to mentally rotate	0	D*	-1	-4
Cognitive Asynchrony	A person who frequently thinks differently than others about things	0		-2	-4
	Negative statements ranked lower in Factor Group 2 array than in other factor arrays				
Teamwork	One who has good listening skills, and who communicates well with others	0	D*	4	2
Resilience	A person who sees challenges as opportunities for growth	-1	D*	0	4
Resilience	A person who remains committed even when against tremendous setbacks	-2	D*	0	1
Teamwork	A person who willingly acts as a team member	-2	D*	3	0
Teamwork	A person who gets along well with others and is able to work well in diverse groups of people	-2	D*	3	0
	Lowest Ranked Statements				
Computational Literacy	A person who enjoys computer programming and has a knack for using programming languages	-5	D*	-5	-2

Table 17: Relative rankings of statements in factor group one

the Navy for 10 years or more. This might explain group one's preference towards far transfer, metacognition and situation awareness traits, as these are highly salient attributes for the purpose of developing new technologies. The perspective of group one suggests that intellectual readiness should emphasize training one's perceptions and awareness to become better and more accurate decision makers.

4.3.1.2. FACTOR GROUP TWO

Factor group two was defined by 32 participants and explained 8% of the study variance with an eigenvalue of 8. 41% were female, 66% were older than 34 years old, and 53% had a bachelor's degree or higher. 50% were serving on active duty in the Navy, 30% were working in the private sector, and 20% were working for the government. 46% of group one had been affiliated with the Navy for more than 10 years, and 53% reported moderate or higher familiarity and knowledge of the Navy.

These people ranked being able to adjust their thinking strategies when necessary as their most important attribute to intellectual readiness. Teamwork and emotion regulation were ranked higher in this group than in any other group. This group ranked being consciously aware of your own cognitive processes very high, which contrasts significantly with both groups one and three, who ranked that statement low.

Anticipatory thinking, mechanical comprehension, and computational literacy were all ranked lowest by group two compared to the other two groups. Interestingly, group two ranked all statements representing intellectual curiosity very low, whereas groups one and three ranked intellectual curiosity as moderate or high. This was a significant difference with the other two groups.

Statements that represented teamwork, such as good listening and communication skills, and being able to get along with others were all

Attribute	Highest Ranked Statements	Factor Group 2	Consensus/ Distinguishing	Factor Group 1	Factor Group 3
Metacognition	A person who can adjust their thinking strategies when necessary	5	D	3	3
	Positive statements ranked higher in Factor Group 1 array than in other factor arrays				
Emotion Regulation	One who maintains a stead state emotionally, especially when stressed	4	D*	-1	-2
Teamwork	One who has good listening skills, and who communicates well with others	4	D*	0	2
Emotion Regulation	One who is self-aware of their emotions and can control their emotions	3	D*	-3	-1
Teamwork	A person who gets along well with others and is able to work well in diverse groups of people	3	D*	-2	0
Situation Awareness	A person who perceives situations quickly and understands the downstream effects	3	D*	3	0
Metacognition	One who is conciously aware of their own cognitive processes	2	D*	0	-3
Emotion Regulation	A person who is comfortable with ambiguity and uncertainty	1	C	1	1
Teamwork	A person who willingly acts as a team member	1		-2	1
Pattern Recognition	A person who demonstrates a systematic way of thinking; good at procedural tasks	0	D*	-1	-2
	Negative statements ranked lower in factor group 2 array than in other factor arrays				
Anticipatory Thinking	A person who likes to play with new ideas and can think about things in new ways	0	D*	2	4
Far Transfer	A person who has a solid understanding of a broad range of topics	0	C*	1	0
Intellectual Curiosity	A person who asks questions frequently	-1		0	3
Intellectual Curiosity	A person with a strong desire to explore the unknown and push the limits of how things are done	-1	D	0	3
Anticipatory Thinking	A person who can engage in mental time travel to simulate what the future might look like	-1	D	1	-1
Cognitive Asynchrony	A person who frequently thinks differently than others about things	-2	D	0	-1
Pattern Recognition	A person who does well solving complex puzzles	-2	D*	-1	2
Anticipatory Thinking	A person who asks "what if" more than "what is"	-2	D*	1	-1
Mechanical	A person who understands how the parts of a system work together, like engines or electricity	-2	D*	1	-1
Mechanical	A person who likes to tinker with things, taking them apart and putting them back together	-3	D*	-1	1
Cognitive Asynchrony	A person with an independent point of view that is frequently very different from their peer group	-3	D*	-2	-3
Computational Literacy	A person who is naturally comfortable with math	-4		-3	-4
Computational Literacy	A person who often thinks and sees things in mathmatical relations	-4		-3	-3
	Lowest Ranked Statements				
Computational Literacy	A person who enjoys computer programming and has a knack for using programming languages	-5	D*	-5	-2

Table 18: Relative rankings of statements in factor group two

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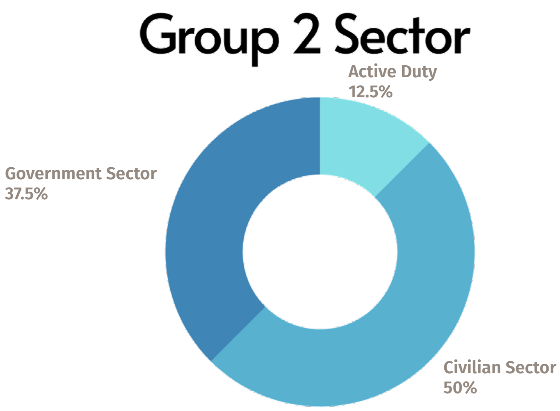
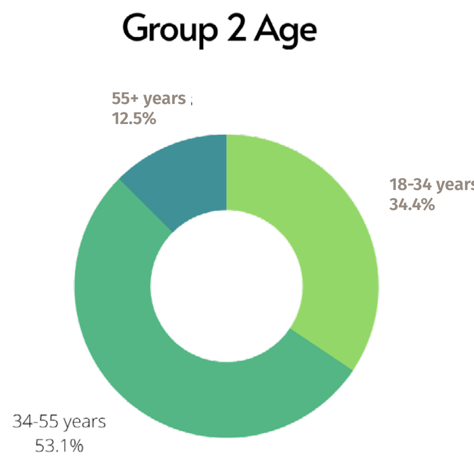
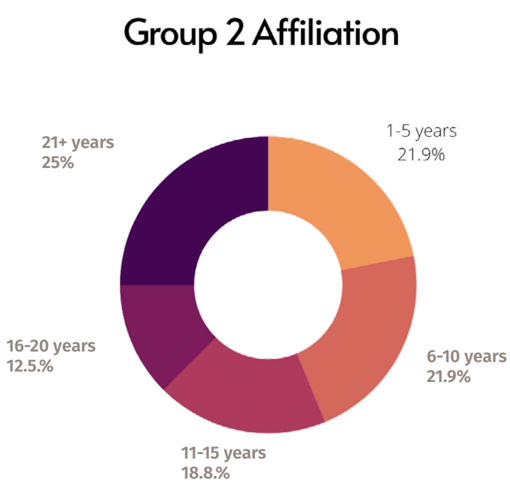
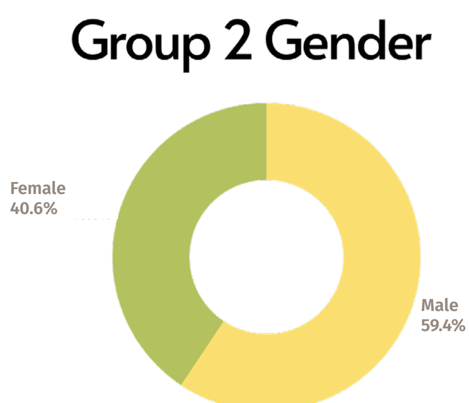
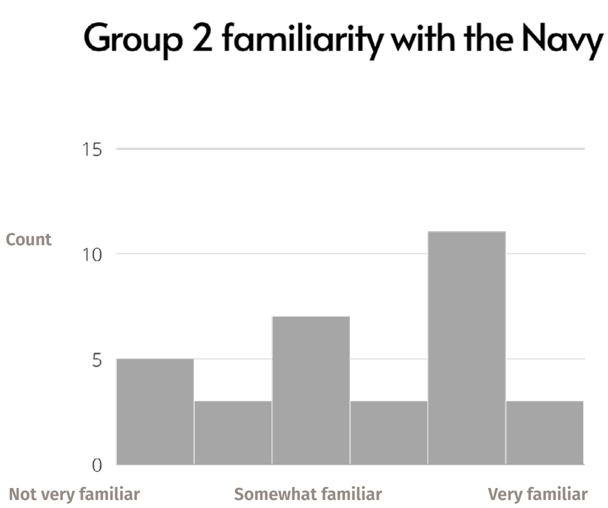
Group Two Demographics

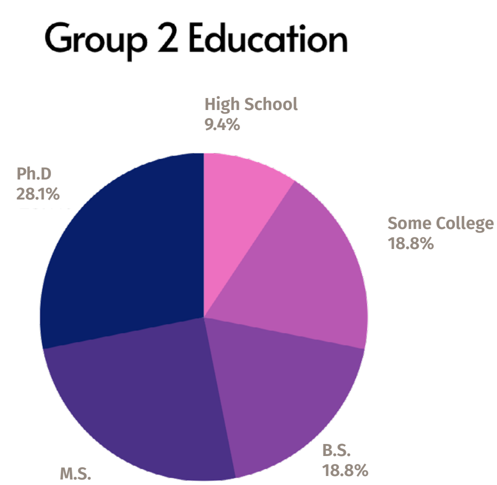












ranked higher than any other group. Being able to control one's emotions and maintaining a steady emotional state were also ranked higher in this group than in any other group. These are all traits that have profound effects on team effectiveness. Conversely, group two considered things like being able to work with machines or being good at programming as irrelevant. Examining the factor array for group two, we might interpret members of this group as placing less emphasis on any one individual's abilities, and instead prioritizing the capabilities that contribute to a team effort.

Two thirds of this group were older and half were active duty military, which might explain this emphasis, considering these individuals probably have had a significant amount of leadership experience and are more likely to think of accomplishments in terms of a group effort. Not surprisingly, thinking differently than others and having an independent point of view were ranked lowest by this group, which reflects a de-emphasis on individuality and a clear preference for group coherence and identity.

The perspectives of group two suggests that intellectual readiness should emphasize training that strengthens teams and reinforces the importance of teamwork; characteristics that make individuals better members of an organization so that the organization can better function.

4.3.1.3. FACTOR GROUP THREE

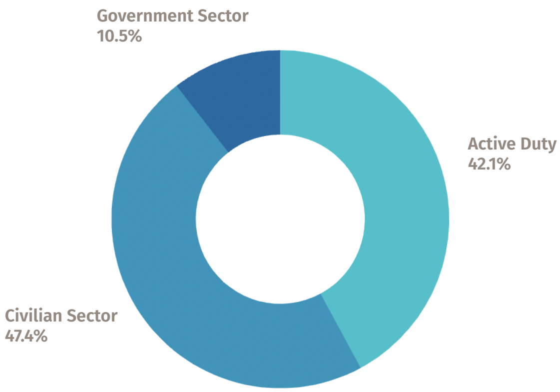
Factor group three was defined by 19 participants and explained 7% of the study variance with an eigenvalue of 7. 67% were male, average age was 26 years old, two thirds were less than 34 years old. 68% had less than a bachelor's degree. 42% were serving on active duty in the Navy, 47% were working in the civilian sector, and 11% were working in the government. 84% of group three had been affiliated with the Navy for less than 10 years, with the average affiliation time

Attribute	Highest Ranked Statements	Factor Group 3	Consensus/ Distinguishing	Factor Group 1	Factor Group 2
Intellectual Curiosity	A person who has a strong desire to know and understand things	5	D	1	1
	Positive statements ranked higher in Factor Group 1 array than in other factor arrays				
Anticipatory Thinking	A person who likes to play with new ideas and can think about things in new ways	4	D*	2	0
Resilience	A person who sees challenges as opportunities for growth	4	D*	-1	0
Intellectual Curiosity	A person with a strong desire to explore the unknown and push the limits of how things are done	3	D*	0	-1
Intellectual Curiosity	A person who asks questions frequently	3	D*	0	-1
Anticipatory Thinking	A person who asks "what if" more than "what is"	2	D*	-1	-2
Emotion Regulation	A person who is comfortable with ambiguity and uncertainty	1	C	1	1
Mechanical	A person who likes to tinker with things, taking them apart and putting them back together	1	D*	-1	-3
Teamwork	A person who willingly acts as a team member	1		-2	1
Resilience	A person who remains committed even when against tremendous setbacks	1	D*	-2	0
Resilience	A person who believes they can achieve whatever they set their mind to	0	D*	-4	-1
	Negative statements ranked lower in factor group 2 array than in other factor arrays				
Situation Awareness	A person who perceives situations quickly and understands the downstream effects	0	D*	3	3
Far Transfer	A person who has a solid understanding of a broad range of topics	0	C*	1	0
Metacognition	A person who evaluates the way they think and chooses appropriate decision making strategies	0	D*	2	1
Situation Awareness	One who sees the chessboard from both sides; one who grasps the whole situation	-1	D*	2	0
Anticipatory Thinking	A person who can engage in mental time travel to simulate what the future might look like	-1	D	1	-1
Emotion Regulation	One who maintains a steady state emotionally, especially when stressed	-2		-1	4
Pattern Recognition	One who quickly recognizes patterns	-2	D*	3	2
Pattern Recognition	A person who demonstrates a systematic way of thinking; good at procedural tasks	-2	D*	-1	0
Cognitive Asynchrony	A perosn with an independent point of view that is frequently very different from their peer group	-3	D	-2	-3
Metacognition	One who is conciously aware of their own cognitive processes	-3	D*	0	2
Computational Literacy	A person who is naturally comfortable with math	-4		-3	-4
Mechanical	A person who can interpret and manipulate visual information, like being able to mentally rotate	-4	D*	0	-1
	Lowest Ranked Statements				
Cognitive Asynchrony	One who is unconcerned with social norms; a strong, independent personality	-5		-4	-3

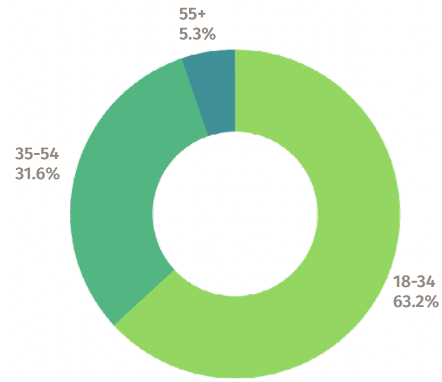
Table 19: Relative rankings of statements in factor group three

Group Three Demographics

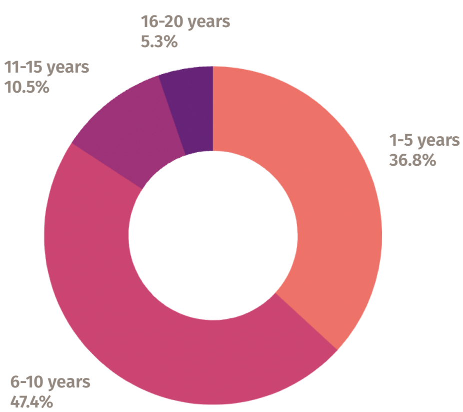
Group 3 Sector



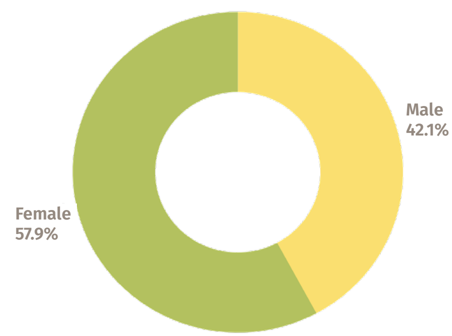
Group 3 Age



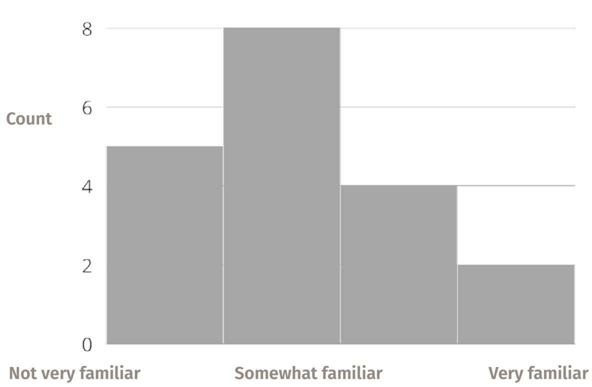
Group 3 Affiliation



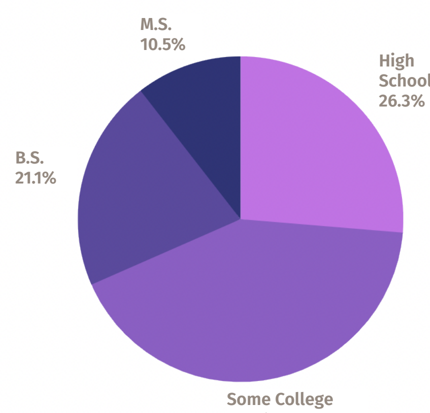
Group 3 Gender



Group 3 familiarity with the Navy



Group 3 Education



of 5 years. Familiarity with the Navy skewed low, with 61% reporting moderate or less familiarity and knowledge of the Navy.

These people ranked having a strong desire to know and understand things as their most important attribute in the context of intellectual readiness. Group three described their ideal as a person who likes to play with new ideas and can think about things in new ways; who has a strong desire to explore the unknown and push the limits of how things are done; one who asks questions frequently, and who asks "what if" more than "what is." Group three also considered people who see challenges as opportunities for growth, who remain committed even when against tremendous setbacks, and who believe they can achieve whatever they set their mind to as vitally important to the concept of intellectual readiness. Groups two and one ranked these far lower.

The characteristics that group three used to describe intellectual readiness all suggest a strong sense of individuality--a person's degree of intellectual curiosity; their ways of thinking; their resilience. This group strongly prioritized characteristics that reflect a sense of curiosity and a desire towards exploration (e.g., people with a strong desire to explore the unknown and push the limits of how things are done, and who see challenge as an opportunity for growth.

This group was far younger, less educated, and less familiar with the Navy or the government than the other groups. They clearly derive less identity from teams, and more from individual attributes and characteristics. One way of interpreting group three is to say that they are young and idealistic, and that their viewpoints reflect their relative inexperience. Another way of interpreting group three is to say that these people's ideals have not been constrained by organizational influences as much as other groups, and as such they retain a strong sense of individuality, determination, and drive to push themselves. Accordingly, intellectual readiness to this group prioritizes training one's mind, and controlling one's thoughts. These priorities strongly signal influences from Stoic philosophy, or perhaps the popularity of the mindfulness movement.

The perspectives of group three suggests that intellectual readiness should emphasize training that disciplines one's mind and teaches techniques to gain more deliberate control over one's mental apparatus.

Conclusion

"If you are functioning within the organization, you have no need to innovate or change things. You are probably more likely to reinforce the system that feeds you."
- Historian, Navy History and Heritage Command

"We don't do innovation here. We do innovation theatre. We are innovation thespians."
- Navy O5, San Diego

5. Conclusion

The unique perspectives extracted above represent a constellation of opinions and priorities. The variance between groups represents the potential differences in opinions that stem from factors such as age and education, and also factors such as experience within the organization of the Navy, or experience in the working environment writ large.

In exploring the differences and similarities that exist between each participant in this study, we can begin to develop a picture of what it means to be intellectually ready from the perspectives of both young and old, in uniform and not. No single line can be drawn to separate these groups into tidy piles by age or gender. Rather, it is important to consider their perspectives holistically, and within those analyses do we find clarity with regards to how the US Navy might proceed to create selection criteria for tomorrow's sailors, and training programs that prepare them.

So what is intellectual readiness? The answer is: it depends. The combined analysis represented here reflects broad consensus about the importance of having awareness of how we think; about our personal biases and prisons of thought that can trap us and limit our creativity when problem solving. The centrality of teamwork is also prominent throughout this data, and attributes that contribute to team cohesiveness and effectiveness were prominently and consistently ranked in this study. Broad consensus also emerged about the relative unimportance of skills such as computational literacy and mechanical comprehension. Such skills may have utility in tomorrow's fight, but fall behind other more important attributes of the cognitive and psychological space.

As was mentioned earlier, it is commonly quipped that "all models are wrong, but some are useful." This is a healthy attitude, in my opinion, because it is both tempting and easy to become enamored with models that elegantly describe how pieces of the puzzle fit together, and to become convinced that such models reflect absolute truth. The reality is, concepts such as intellectual readiness are inherently complex, and any attempt to model it necessarily reduces that complexity and therefore reduces its accuracy and reliability.

The participants in this study represent both the stakeholders themselves, and individuals who are expertly aware and familiar with emerging technologies. In other words, the data presented in this report represent informed voices. These were not college sophomores participating in a survey project for credit. These were active duty sailors, full-time government and civilian scientists and engineers, all of which have a vested interest in the concept of intellectual readiness because it is necessary in their daily lives.

The ultimate goal of models such as this one is to serve as a guidepost that point administrators and planners in the directions where they should prioritize efforts and investments. This model and its subsequent validation provide such guidance. Should it be heeded, the traits and characteristics described above represent worthy goals towards developing and preparing tomorrow's Navy.

Although there were many voices reflected here, there was one voice that spoke in unison through all of the participants, both through the model development effort as well as its validation: although technology is critical to gaining strategic advantage, it is the **people** using that technology that make the biggest difference. That much was true yesterday, is still true today, and will be true tomorrow.

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Appendices

"I think you have to discuss the value of giving younger officers command opportunities. Nimitz took command of destroyer Decatur when he was just 22. Raymond Spruance had his first ship command at 26, William Halsey, Jr. at 30, and Ernest J. King at 36. Command at or before 30 was much more common a century ago than it is now. I think it is reasonable to ask what impact this had (or has had) on intellectual readiness."

- Author of Naval History and Innovation

7. Attribute Rankings

SITUATION AWARENESS

Situation Awareness Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who perceives situations quickly and understands the downstream effects	3	3	0	2	0.282
One who sees the chessboard from both sides; one who grasps the whole situation	2	0	-1	0	0.295
Being able to rapidly assess situations and project the consequences of actions into the future	5	1	1	2	0.554

Table 20: Statements comprising the attribute Situation Awareness. Z score variance for this factor indicates moderate disagreement across all groups.

FAR TRANSFER

Far Transfer Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who has a solid understanding of a broad range of topics	1	0	0	0	0.001
A person who can take knowledge from one domain, and apply it to another	4	2	2	3	0.105
A person who sees connections between different ideas or problems easily, often where others don't	4	2	2	3	0.311

Table 22: Statements comprising the attribute Far Transfer. Z Score variance is very low, indicating a high degree of agreement across all three groups.

METACOGNITION

Metacognition Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who can adjust their thinking strategies when necessary	3	5	3	4	0.078
A person who evaluates the way they think and chooses appropriate decision making strategies	2	1	0	1	0.131
One who is consciously aware of their own cognitive processes	0	2	-3	0	0.587

Table 23: Statements comprising the attribute Metacognition. Z Score variance ranges from very low to moderately high, which indicates the factor's salience varies depending on the group's perspective.

COGNITIVE ASYCHRONY

Cognitive Asynchrony Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who frequently thinks differently than others about things	0	-2	-1	-1	0.052
One who is unconcerned with social norms; a strong, independent personality	-4	-3	-5	-4	0.065
One who is consciously aware of their own cognitive processes	-2	-3	-3	-3	0.093

Table 24: Statements comprising the attribute Cognitive Asynchrony. Z Score variance is very low, indicating a high degree of agreement across all three groups.

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COMPUTATIONAL FLUENCY

Computational Literacy Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who is naturally comfortable with math	-3	-4	-4	-4	0.035
A person who often thinks and sees things in mathematical relations	-3	-4	-3	-3	0.119
A person who enjoys computer programming and has a knack for using programming languages	-5	-5	-2	-4	0.266

Table 25: Statements comprising the attribute Computational Literacy. Z Score variance is very low, indicating a high degree of agreement across all three groups.

ANTICIPATORY THINKING

Anticipatory Thinking Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who can engage in mental time travel to simulate what the future might look like	1	-1	-1	0	0.113
A person who likes to play with new ideas and can think about things in new ways	2	0	4	2	0.331
A person who asks "what if" more than "what is"	-1	-2	2	0	0.46

Table 26: Statements comprising the attribute Anticipatory Thinking. Z Score variance is moderate, indicating a disagreement regarding this factor across the groups.

INTELLECTUAL CURIOSITY

Intellectual Curiosity Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who asks questions frequently	0	-1	3	1	0.454
A person with a strong desire to explore the unknown and push the limits of how things are done	0	-1	3	1	0.498
A person who has a strong desire to know and understand things	1	1	5	2	0.613

Table 27: Statements comprising the attribute Intellectual Curiosity. Z score variance for this factor indicates moderate disagreement across all groups.

MECHANICAL COMPREHENSION

Mechanical Comprehension Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who understands how the parts of a system works together, like engines or electricity	1	-2	-1	-1	0.214
A person who likes to tinker with things, taking them apart and putting them back together	-1	-3	1	-1	0.466
A person who can interpret and manipulate visual information, like being able to mentally rotate objects and shift visual perspectives	0	-1	-4	-2	0.545

Table 28: Statements comprising the attribute Mechanical Comprehension. Z Score variance is very low, indicating a high degree of agreement across all three groups.

PATTERN RECOGNITION

Pattern Recognition Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who demonstrates a systematic way of thinking; good at procedural tasks	-1	0	-2	-1	0.138
A person who does well solving complex puzzles	2	-2	0	0	0.445
One who quickly recognizes patterns	3	2	-2	1	0.666

Table 29: Statements comprising the attribute Pattern Recognition. Significant Z score variance indicates this factor created broad disagreement amongst the groups.

TEAMWORK

Teamwork Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who willingly acts as a team member	-2	1	1	0	0.309
One who has good listening skills, and who communicates well with others	0	4	2	2	0.433
A person who gets along well with others and is able to work well in diverse groups of people	-2	3	0	0	0.57

Table 30: Statements comprising the attribute Teamwork. Z Score variance is significant, indicating that this factor was controversial amongst our groups.

RESILIENCE

Resilience Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who remains committed even when against tremendous setbacks	-2	0	1	0	0.171
A person who believes they can achieve whatever they set their mind to	-4	-1	0	-2	0.563
A person who sees challenges as opportunities for growth	-1	0	4	1	0.858

Table 31: Statements comprising the attribute Resilience. Z Score variance is moderate to high, indicating a high degree of disagreement across all three groups.

EMOTION REGULATION

Emotion Regulation Statement Descriptions	Group One Ranking	Group Two Ranking	Group Three Ranking	Average Ranking	Z Score Variance
A person who is comfortable with ambiguity and uncertainty	1	1	1	1	0.017
One who is self-aware of their emotions and can control their emotions	-3	3	1	0	0.797
One who maintains a steady state emotionally, especially when stressed	-1	4	-2	0	0.867

Table 32: Statements comprising the attribute Emotion Regulation. Z Score variance is mostly high, indicating a high degree of disagreement across all three groups.

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8. Factor Arrays

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Group Two


Group Three
-5
-4
-3
-2
-1
0
1
2
3
4
5
One who is unconcerned with social norms; a strong,
A person who is naturally comfortable with math
** ◄ A person who can interpret and manipulate visual information,
* A person with an independent point of view that is frequently very
** ◄ One who is consciously aware of their own cognitive processes
A person who often thinks and sees things in mathematical relations
One who maintains a steady state emotionally, especially when
** ◄ One who quickly recognizes patterns
** ► A person who enjoys computer programming and has a knack for using
** ◄ A person who demonstrates a systematic way of thinking; good at
** A person who understands how the parts of a system works together, like
** ◄ One who sees the chessboard from both sides; one who grasps the
A person who can engage in mental time travel to simulate what
A person who frequently thinks differently than others
* One who is self-aware of their emotions and can control their emotions
** ◄ A person who perceives situations quickly and understands the
** ► A person who believes they can achieve whatever they set their mind
A person who has a solid understanding of a broad range of topics
** ◄ A person who evaluates the way they think and chooses appropriate
** A person who gets along well with others and is able to work well in diverse
** A person who does well solving complex puzzles
A person who is comfortable with ambiguity and uncertainty
** ► A person who likes to tinker with things, taking them apart and
A person who willingly acts as a team member
** ◄ Being able to rapidly assess situations and project the consequences of
A person who remains committed even when against tremendous
A person who can take knowledge from one domain, and apply it to
** One who has good listening skills, and who communicates well with
** ► A person who asks what if more than what is
A person who sees connections between different ideas
** ► A person with a strong desire to explore the unknown and push the limits
** ► A person who asks questions frequently
** ◄ A person who can adjust their thinking strategies when necessary
** ► A person who likes to play with new ideas and can think about things in
** ► A person who sees challenges as opportunities for growth
** ► A person who has a strong desire to know and understand things
Legend
* Distinguishing statement at P< 0.05
** Distinguishing statement at P< 0.01
► z-Score for the statement is higher than in all other factors
◄ z-Score for the statement is lower than in all other factors
COGNITIVE ASYNCHRONY
FAR TRANSFER
COMPUTATIONAL LITERACY
METACOGNITION
ANTICIPATORY THINKING
SITUATION AWARENESS
MECHANICAL COMPREHENSION
PATTERN RECOGNITION
TEAMWORK
INTELLECTUAL CURIOSITY
RESILIENCE
EMOTION REGULATION

9. Consensus Vs. Disagreement

Composite values sorted by consensus vs. disagreement

Factor Category	Nm	Statement	Group 1	Group 2	Group 3	Average Factor Score
Metacognition	19	A person who can adjust their thinking strategies when necessary	3	5	3	4
Far Transfer	10	A person who can take knowledge from one domain, and apply it to another	4	2	2	3
Far Transfer	11	A person who sees connections between different ideas or problems easily, often where others don't	4	2	2	3
Situation Awareness	32	Being able to rapidly assess situations and project the consequences of actions into the future	5	1	1	2
Intellectual Curiosity	13	A person who has a strong desire to know and understand things	1	1	5	2
Anticipatory Thinking	4	A person who likes to play with new ideas and can think about things in new ways	2	0	4	2
Situation Awareness	31	A person who perceives situations quickly and understands the downstream effects	3	3	0	2
Teamwork	36	One who has good listening skills, and who communicates well with others	0	4	2	2
Metacognition	21	A person who evaluates the way they think and chooses appropriate decision making strategies	2	1	0	1
Pattern Recognition	26	One who quickly recognizes patterns	3	2	-2	1
Resilience	30	A person who sees challenges as opportunities for growth	-1	0	4	1
Emotion Regulation	9	A person who is comfortable with ambiguity and uncertainty	1	1	1	1
Intellectual Curiosity	15	A person who asks questions frequently	0	-1	3	1
Intellectual Curiosity	14	A person with a strong desire to explore the unknown and push the limits of how things are done	0	-1	3	1
Far Transfer	12	A person who has a solid understanding of a broad range of topics	1	0	0	0
Situation Awareness	33	One who sees the chessboard from both sides; one who grasps the whole situation	2	0	-1	0
Teamwork	34	A person who gets along well with others and is able to work well in diverse groups of people	-2	3	0	0
Emotion Regulation	8	One who maintains a steady state emotionally, especially when stressed	-1	4	-2	0
Pattern Recognition	25	A person who does well solving complex puzzles	2	-2	0	0
Teamwork	35	A person who willingly acts as a team member	-2	1	1	0
Metacognition	20	One who is consciously aware of their own cognitive processes	0	2	-3	0
Anticipatory Thinking	5	A person who can engage in mental time travel to simulate what the future might look like	1	-1	-1	0
Anticipatory Thinking	6	A person who asks what if more than what is	-1	-2	2	0
Resilience	28	A person who remains committed even when against tremendous setbacks	-2	0	1	0
Emotion Regulation	7	One who is self-aware of their emotions and can control their emotions	-3	3	-1	0
Mechanical Comprehension	16	A person who understands how the parts of a system works together, like engines or electricity	1	-2	-1	-1
Cognitive Asynchrony	22	A person who frequently thinks differently than others about things	0	-2	-1	-1
Mechanical Comprehension	17	A person who likes to tinker with things, taking them apart and putting them back together	-1	-3	1	-1
Pattern Recognition	27	A person who demonstrates a systematic way of thinking; good at procedural tasks;	-1	0	-2	-1
Mechanical Comprehension	18	A person who can interpret and manipulate visual information, like being able to mentally rotate objects and shift visual perspectives	0	-1	-4	-2
Resilience	29	A person who believes they can achieve whatever they set their mind to	-4	-1	0	-2
Cognitive Asynchrony	23	A person with an independent point of view that is frequently very different from their peer group	-2	-3	-3	-3
Computational Literacy	2	A person who often thinks and sees things in mathematical relations	-3	-4	-3	-3
Computational Literacy	1	A person who is naturally comfortable with math	-3	-4	-4	-4
Cognitive Asynchrony	24	One who is unconcerned with social norms; a strong, independent personality	-4	-3	-5	-4
Computational Literacy	3	A person who enjoys computer programming and has a knack for using programming languages	-5	-5	-2	-4

Factor Q-sort Values for Statements sorted by Consensus vs. Disagreement

	Nm	Statement	Factor 1	Factor 2	Factor 3	Average Factor Score	Z-score variance
Metacognition	19	A person who can adjust their thinking strategies when necessary	3	5	3	4	0.078
Far Transfer	10	A person who can take knowledge from one domain, and apply it to another	4	2	2	3	0.105
Emotion Regulation	9	A person who is comfortable with ambiguity and uncertainty	1	1	1	1	0.017
Metacognition	21	A person who evaluates the way they think and chooses appropriate decision making strategies	2	1	0	1	0.131
Far Transfer	12	A person who has a solid understanding of a broad range of topics	1	0	0	0	0.001
Anticipatory Thinking	5	A person who can engage in mental time travel to simulate what the future might look like	1	-1	-1	0	0.113
Resilience	28	A person who remains committed even when against tremendous setbacks	-2	0	1	0	0.171
Cognitive Asynchrony	22	A person who frequently thinks differently than others about things	0	-2	-1	-1	0.052
Pattern Recognition	27	A person who demonstrates a systematic way of thinking; good at procedural tasks;	-1	0	-2	-1	0.138
Cognitive Asynchrony	23	A person with an independent point of view that is frequently very different from their peer group	-2	-3	-3	-3	0.093
Computational Literacy	2	A person who often thinks and sees things in mathematical relations	-3	-4	-3	-3	0.119
Computational Literacy	1	A person who is naturally comfortable with math	-3	-4	-4	-4	0.035
Cognitive Asynchrony	24	One who is unconcerned with social norms; a strong, independent personality	-4	-3	-5	-4	0.065
Far Transfer	11	A person who sees connections between different ideas or problems easily, often where others don't	4	2	2	3	0.311
Situation Awareness	31	A person who perceives situations quickly and understands the downstream effects	3	3	0	2	0.282
Anticipatory Thinking	4	A person who likes to play with new ideas and can think about things in new ways	2	0	4	2	0.331
Teamwork	36	One who has good listening skills, and who communicates well with others	0	4	2	2	0.433
Intellectual Curiosity	15	A person who asks questions frequently	0	-1	3	1	0.454
Intellectual Curiosity	14	A person with a strong desire to explore the unknown and push the limits of how things are done	0	-1	3	1	0.498
Situation Awareness	33	One who sees the chessboard from both sides; one who grasps the whole situation	2	0	-1	0	0.295
Teamwork	35	A person who willingly acts as a team member	-2	1	1	0	0.309
Pattern Recognition	25	A person who does well solving complex puzzles	2	-2	0	0	0.445
Anticipatory Thinking	6	A person who asks what if more than what is	-1	-2	2	0	0.46
Mechanical Comprehension	16	A person who understands how the parts of a system works together, like engines or electricity	1	-2	-1	-1	0.214
Mechanical Comprehension	17	A person who likes to tinker with things, taking them apart and putting them back together	-1	-3	1	-1	0.466
Computational Literacy	3	A person who enjoys computer programming and has a knack for using programming languages	-5	-5	-2	-4	0.266
Situation Awareness	32	Being able to rapidly assess situations and project the consequences of actions into the future	5	1	1	2	0.554
Intellectual Curiosity	13	A person who has a strong desire to know and understand things	1	1	5	2	0.613
Pattern Recognition	26	One who quickly recognizes patterns	3	2	-2	1	0.666
Resilience	30	A person who sees challenges as opportunities for growth	-1	0	4	1	0.858
Teamwork	34	A person who gets along well with others and is able to work well in diverse groups of people	-2	3	0	0	0.57
Emotion Regulation	8	One who maintains a steady state emotionally, especially when stressed	-1	4	-2	0	0.867
Metacognition	20	One who is consciously aware of their own cognitive processes	0	2	-3	0	0.587
Emotion Regulation	7	One who is self-aware of their emotions and can control their emotions	-3	3	-1	0	0.797
Mechanical Comprehension	18	A person who can interpret and manipulate visual information, like being able to mentally rotate objects and shift visual perspectives	0	-1	-4	-2	0.545
Resilience	29	A person who believes they can achieve whatever they set their mind to	-4	-1	0	-2	0.563