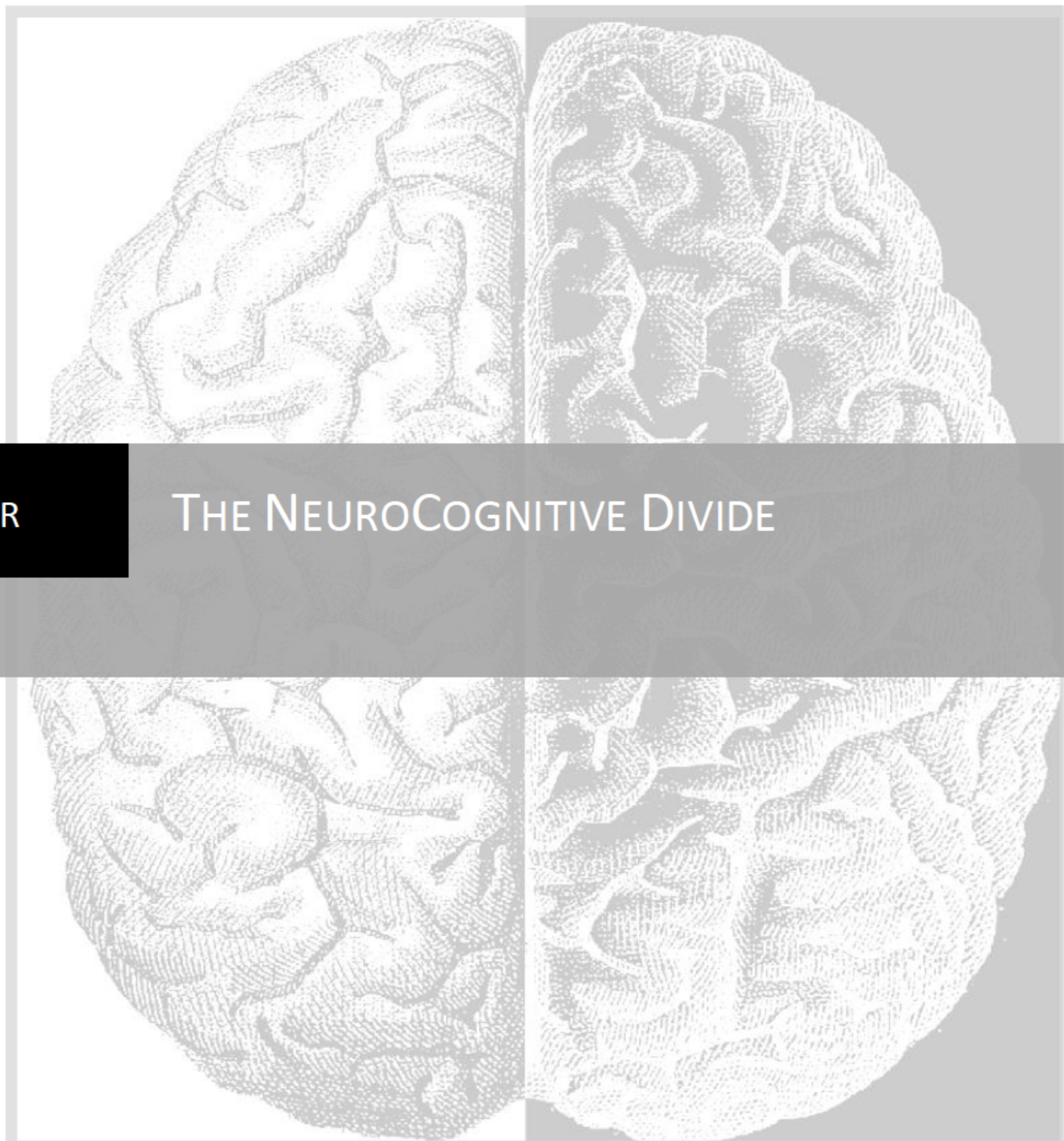
SCITOR

THE NEUROCOGNITIVE DIVIDE



Final Report | (b) (7)(C) [redacted]

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NEUROCOGNITIVE DIVIDE

FINAL REPORT

CONTENTS

EXECUTIVE SUMMARY

This report is the culmination of a year-long investigation of the ways in which neurocognitive function and perception may differ among strategically important populations, and methodical consideration of the potential military implications of those differences in terms of operational styles or even technological development. Cognition among and between peoples is undoubtedly more alike than it is different, which is why it is surprising when culturally-bound interpretations and perceptions diverge. The purpose of the study was to consider whether and, if so, how and to what extent understanding such differences could provide operationally-relevant insights into relative approaches to defense functions.

Since at least the 1960s behavioral science and psychological studies have demonstrated differences in perception, interpretation, response and motivations between Eastern and Western populations. Richard Nisbett's "Geography of Thought" (2003) is a seminal contribution to the field in which he connects the then nascent body of psychological work to cultural structures and values. Nisbett presents a number of broad dichotomies that characterize the major thematic differences between North Western and East Asian thinking patterns, including object versus context biases, and organizing the world in categorical versus relational terms.

More recently neuroscientists have attempted to uncover both the neuroanatomical 'hardware' and mechanisms responsible for some of these differences. With the explosion of neuroscientific tools and increasing sophistication of methods in cognitive science, what once was just a handful of studies has since grown into the field of cultural neuroscience. The premise is sound: the brain is an adaptive structure, which, over the course of development and through various learning mechanisms, changes in response to environmental stimuli. Just as children learn language, they also learn norms, values, gestures and cognitive constructs all of which are heavily influenced by culture. Just as individuals can learn more than one language they can also learn more than one set of ways for viewing the world, but just as one's native or first language provides the construct and basis for learning other languages, the same is likely true of culturally influenced cognitive styles. A Westerner can certainly consider the world in terms of relationships rather than in categorical terms, but it may take a little more effort and a tendency to default towards one way of thinking may influence or bias interpretations, assumptions, and decision making in ways that are not apparent unless explicitly pointed out. Thus, if these biases affect cognitive styles, and cognition can be linked to specific neural structures, networks, and chemicals, neuroscience may be able to learn more about the nature of these differences by understanding the brain systems involved, and the mechanisms that differentiate between these structures.

The study revealed the following findings:

- Neurocognitive differences are most likely to affect operational functions like [redacted] that rely heavily on perception, interpretation, projection and decision-making. The tendency to be influenced by or ignore contextual details, for instance, will shape how one interprets and responds to information and such cultural tendencies are likely to become implicitly embedded in intelligence products over the course of multiple decision-cycles. Thus, in addition to psychological cognitive biases (anchoring, recency, mirror imaging, etc.), ISR and intelligence analysts should also learn and develop mechanisms to account for these neurocognitive biases.
- Understanding the mechanisms underlying neurocognitive differences provides a means to anticipate how those differences may widen or narrow in response to performance disruptors such as fatigue and acute stress. For instance, stress increases reliance on ingrained or habitual processes meaning neurocognitive tendencies may be more prevalent in high-stress scenarios.
- Gene-culture Co-evolutionary Theory posits that cultures have selected for different traits based on their value structures and have shaped the frequencies of related genetic alleles as a result. This study considered the idea that if culture affects genetic selection within a population, we might be able to identify neurocognitive group-average differences between cultures on a population level by examining differences in gene frequency distributions. More often than not, the predictions generated from genetic data did not hold up against behavioral and epidemiological findings. Due to the many opportunities for environmental randomness to affect what is a complex adaptive system, even *if genetic research tools improve,* ***the best method for understanding neurocognitive divergence is to study behavior.***
- If cultural differences in neurocognitive functions provide context-dependent advantages or disadvantages, then the most effective approaches should come from teams that incorporate a diversity of cognitive approaches. Evidence supports this and shows benefits in group diversity beyond that contributed by technical expertise.[1] [redacted] Military decision makers and intelligence analysts, however, are likely far less diverse than Western academia and thus are not as likely to benefit from similar diversity in thought.

[1] Katherine W Phillips, "How Diversity Makes Us Smarter," *Scientific American*, September 16, 2014.

1. INTRODUCTION

Cultural psychology and more recently cultural neuroscience have shown that cultural and regional differences influence not just how people understand the world in the traditional Whorfian sense,[2] but also shapes computations at the neural level. Understanding the nature and extent of these neurocognitive differences may help us better understand the political motivations and approaches to military operations of populations other than our own. This report is the result of a year-long investigation into the many factors that affect Eastern and Western neurocognition and the potential military implications of how those factors may affect, contribute to or shape perception, conceptions, reactions and actions.

The first part of this report covers a set of neurocognitive differences that experimentally have been associated with people who ascribe to collectivist and individualist value structures. Since the field of cultural neuroscience is fairly new, the published literature to date is rather limited and there is very little that applies directly to military skill sets or environments. The latter portion of the study is a methodical consideration of how various neurocognitive differences identified in laboratory settings might manifest in military settings. The factors that have been found to differ between Eastern and Western populations range from cultural constructs such as those discussed in Richard Nesbitt's *The Geography of Thought*, to differences in brain activation patterns. There is even evidence that culture may have imposed selective pressures on preferred traits resulting in population-level differences the frequencies of certain genetic variants. We discuss these factors first against various performance disruptors (fatigue, stress, boredom) and then consider how they might affect specific military functions (Intelligence Surveillance and Reconnaissance, Command and Control, and military-relevant technological development). The resulting analysis provides a set of ideas that subsequent analysis can test using historical and/or behavioral data.

Why consider neurocognitive differences? Despite the limitation of our still nascent understanding of cognitive function, and the many ways nature and nature interact to shape the perception, behavior, and actions of populations, there are a number of reasons to consider how neurocognitive differences and perceptual tendencies affect human military performance.

First, the realization that neurocognitive processes (not just perspectives) differ between human populations has shown us that what we think we understood about psychology and neuroscience may only apply to a small portion of the world's population. Without repeating all of the experiments that have predated that realization, we have no way of knowing which findings generalize and which do not.

[2] The Sapir-Whorf hypothesis or theory of Linguistic Relativity postulates language shapes the way people understand the world.

Second, comparing our own Western neurocognitive processes to Eastern processes may help us better understand how our cognitive tendencies bias or influence our analysis of Eastern political processes and military actions. Most in international politics and military leadership are aware that there are differences between the way Eastern and Western people and institutions approach business negotiations or command, but that awareness is shallow. More information about the mechanisms behind those differences may deepen our understanding of motivations, tendencies, and values structures beyond our own.

Third, thinking through how cultural and biological factors may interact with military contexts helps pinpoint where we should be focusing our analytical efforts. For instance, there are a number of genetic variants associated with risk-taking behavior, which begs the question of whether the distribution of those variants might tell us something about how risky a military may be on the battlefield. [redacted] Considering the potential military implications of neurocognitive differences is then currently an exercise in generating hypotheses, more than deductions to be taken outright. Many of the ideas are testable with a more in depth analysis of cultural influence and historical data.

As such, the remaining sections in this report are an analytic exercise in generating hypothesis about:

- How cultural and neurocognitive differences between Eastern and Western populations might affect performance in the face of a number of performance disruptors common to operational environments, and
- What the implications may be for operational and tactical military processes.

GROUPS OF INTEREST.

Throughout the report we discuss "Eastern" and "Western" populations and cultural groups broadly, but it is important to keep in mind that these populations are by no means homogenous, and that there are many rich subcultures within and across each that would have comparable influence over development, behavior, and cognition. In order to study the interesting ways that behavior and cognition are influenced by culture we must make distinctions somewhere, and so we have followed that most often cited in the literature. Though the reader – presumably coming from a Western perspective – may think Eastern collectivistic perceptions and behaviors to be anomalous, North Western individualism is actually far more rare across the globe. And even though North Western culture is an outlier in this regard, the vast majority of cognitive and neuroscientific studies are conducted in North Western regions on North Western populations. We presume the findings we draw from those studies apply to all humans, but as Hienrich and Heine pointed out, many of these studies on Western Educated Individualistic Rich and Democratic ("WEIRD")[3] do not generalize to non-WEIRD populations. The present study has included as much culturally and regionally-specific data as possible, but due to the WEIRD bias in the literature available we recognize that many of the studies herein that refer to patterns in chemical signaling, or behavioral responses for stress, for instance, may also not generalize. Despite this limitation, the inability to apply findings from WEIRD populations to others highlights the importance of studying how cognition and behavior differ between cultural and regional groups and at what level cognition is affected. Does culture merely change the memory structures people build over their lives, or can it also affect the structure, connections, and chemical signaling mechanisms? The answer seems to be all of the above.

THE CULTURALLY SHAPED BRAIN.

The brain is an inherently plastic, adaptive and dynamic organ, which can be shaped both in structure and function by any environmental factor to include language, cultural norms, values, and other experiences. Though some events, experiences, and interactions are more influential than others, all of them stimulate the formation or removal of connections between neurons and strengthening or weakening networks. There are key developmental (or 'sensitive') periods in early life in which the brain is especially sensitive to environmental influence. For instance, immediately after birth when the developing visual system is learning how to interpret light information, it is so sensitive to environmental factors that if one eye is occluded (due to cataract, or some other anomaly) the brain permanently shifts to interpret information coming only from the healthy

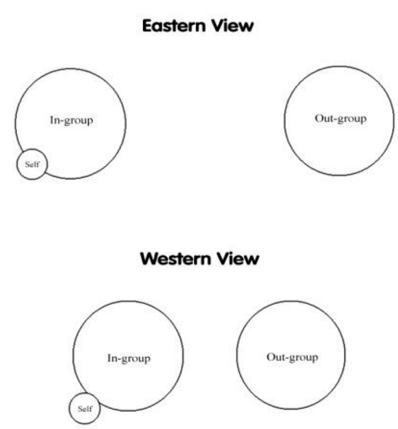


FIGURE 1: The Eastern and Western view of the self, relative to friends and family. From http://www.ccaps.net/blog/easterner-westerner/

[3] Joseph Henrich, Steven J Heine, and Ara Norenzayan, "The Weirdest People in the World?," *Behavioral and Brain Sciences* 33, no. 2 (June 15, 2010): 61–83, doi:10.1017/S0140525X0999152X.

eye. Even if the occluded eye is repaired within days of birth, communication between the occluded eye and the brain is forever compromised.[4] The most apparent example of how culture influences brain mapping during such sensitive periods is the influence of language on one's ability to distinguish between phonetic elements outside their native language. If, for instance, a Japanese child does not hear English /r/ and /l/ sounds during this developmental stage (before 3 or 4), he or she will likely never be able to perceive the difference between these phonemes, nor produce them. While no one has identified a similar sensitive period for learning cultural norms and values, children have an easier time adjusting to a new culture compared to adults suggesting, like language, culture is learned at an early age. Moreover, psychological findings show that regional dichotomies such as emphasis on individualistic versus collectivistic values, and categorical versus relationship-based approaches to organizing the world, shape perception, attention, and even the definition of self.

Nisbett summarizes a number of dichromatic axes in his book *The Geography of Thought* including: perceptual emphasis on objects versus contexts, seeing the world as made of objects versus substances, belief in more or less control over the environment and one's circumstances, a sense that the world is relatively stable versus the idea it is constantly in flux; a tendency to organize the world in terms of categories versus relationships, and valuing debate to identify a single correct truth versus a drive towards harmonious agreement and compromise in which there may be more than one correct answer (see Figure 2). As a set, the Western approach is decidedly more individualistic; it defines and rewards individuals in terms of his or her inherent character and as an agent with power to affect his or her world. Western culture celebrates individual accomplishment and those who stand out from the crowd, often by being openly at odds with the main stream (e.g., trailblazers, mavericks, and those who 'think outside the box'). The Eastern collective view, on the other hand, defines the individual in terms of his or her relationships (father, brother, mentor, etc.) and sees personality attributes as a function of the context rather than as traits inherent to a person's identity. Collectivism also values compromise above debate to maintain harmony amongst highly interdependent social structures.

[4] Doctors will prevent this unbalanced brain mapping between eyes by blind folding the baby until the impaired eye can be fixed. When both eyes are healthy the blindfold can be removed and they will map normally and equally to the visual cortex.

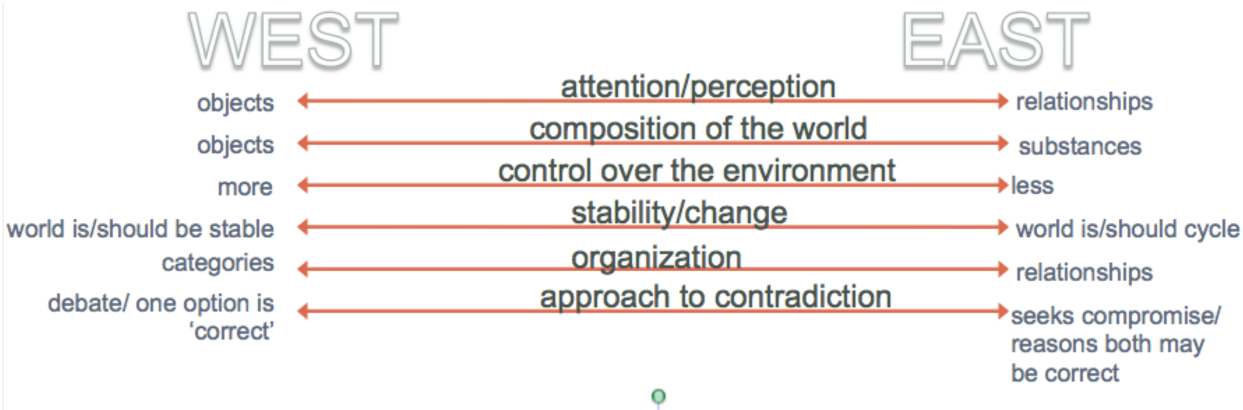
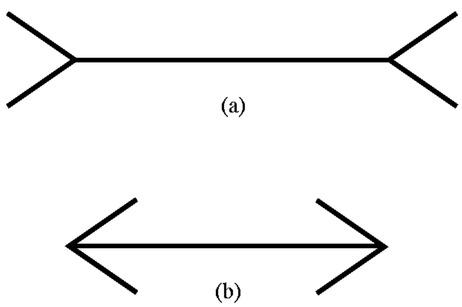


Figure 2: Dichotomies of thought between Eastern and Western populations. Adapted from Nesbitt, 2003.



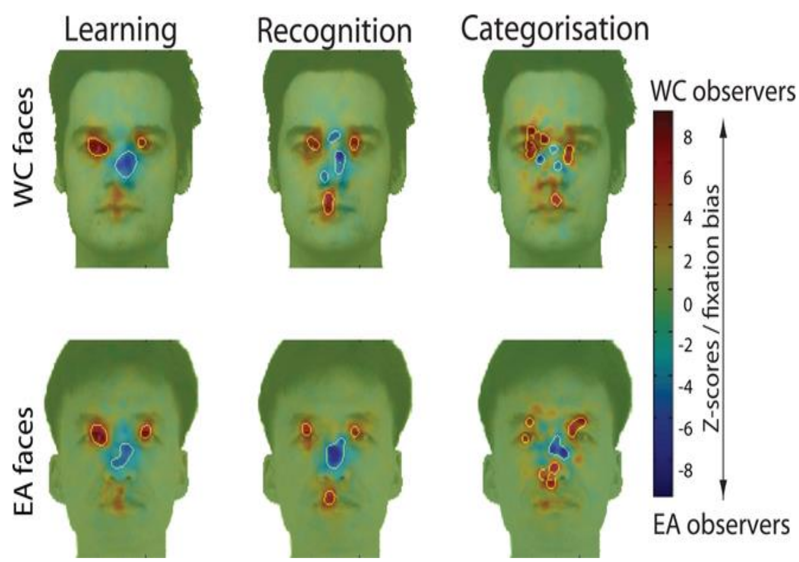


FIGURE 3: LEFT. The Müller-Lyer Illusion. RIGHT: Gaze heat maps highlighting different attention patterns between East Asian observers (blue clusters) and Western observers (red clusters). The patterns were not affected by whether one was viewing a face from his or her own or the other culture. (Image from Blais, et al.,2008.)

One of the earliest demonstrations that these cultural dichotomies affect perception comes from the classic Müller-Lyer Illusion (Figure 3, left). Westerners are more likely to wrongly respond that the horizontal lines are unequal in length than Easterners. Nesbit argues that because Easterners more often consider context, they have more experience accounting for the influence the arrows have in shaping one's perception, and are less susceptible to the optical illusion.

Gaze behavior shows that an emphasis on objects versus context affects how people deploy their attentional resources. An eye tracking study[5] compared the gaze patterns of East Asian

[5] Caroline Blais et al., "Culture Shapes How We Look at Faces," ed. Alex O Holcombe, *PLoS ONE* 3, no. 8 (August 20, 2008): e3022, doi:10.1371/journal.pone.0003022.s004.

and Western subjects when viewing faces (Figure 3, right). Western participants spent more time looking at facial features as distinct objects (red heat map clusters in Figure 4). East Asian participants on the other hand, gazed more consistently at the middle of the faces (blue heat map clusters) processing the face as a whole rather than as a composition of features. While interesting, differing susceptibility to optical illusions and patterns in gaze behavior could merely be the result of culturally-engrained habit, and does not provide evidence that culture shapes brain structure beyond the connections formed to make habit-related memories. For

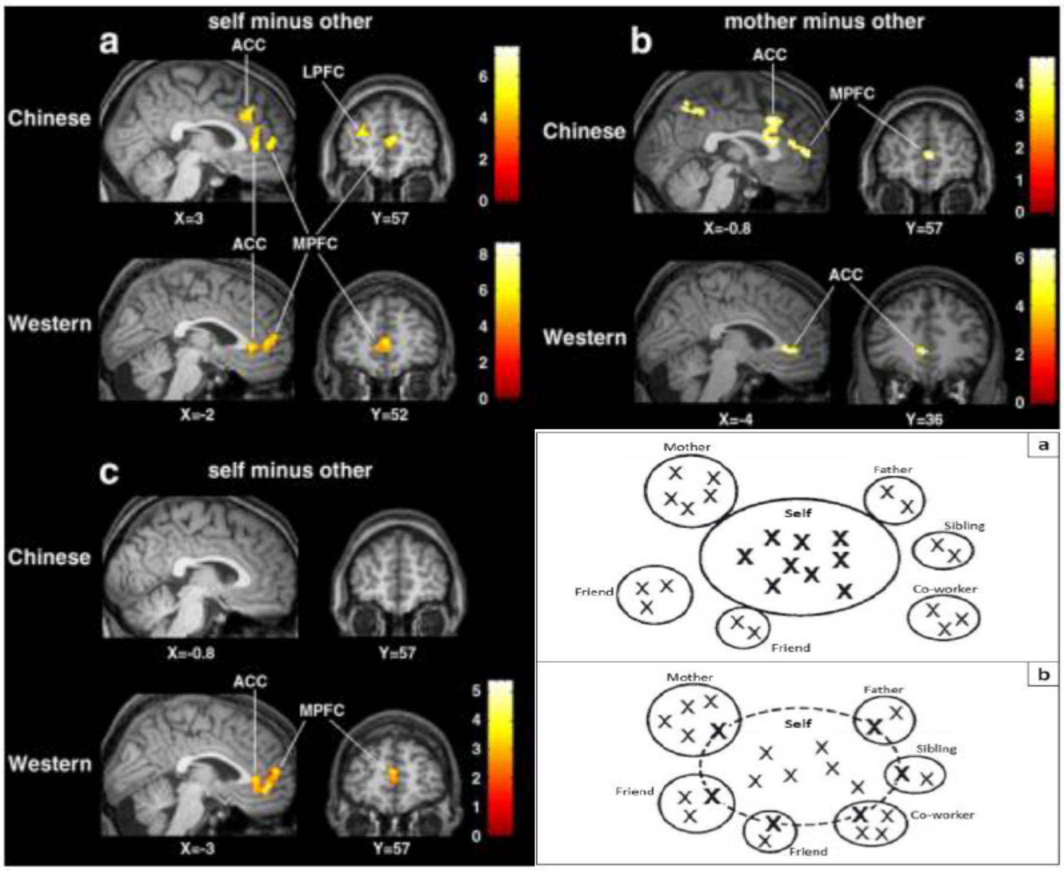


FIGURE 4: Cultural differences in definitions of 'self' and 'other' affect neural representations of familial concepts. Top left: both Chinese and American participants represent 'self' and 'other' in slightly different areas of the brain. Bottom left: Western conceptions of 'other' are much more different than their conceptions of themselves, compared to Chinese participants. Top Right: The representation of one's mother if similar to the pattern associated with 'self' in Chinese participants, but appeared more like the pattern associated with 'other' in Western participants. Bottom Right: An illustration of individualistic (top) versus collectivistic (bottom) definitions of the self that is supported by the neuroimaging data. Images from Markus & Kitayama (1991).

this reason, cultural neuroscientists turned to neuroimaging methodologies to investigate whether cultural differences affected brain function as well as behavior.

One such study tested whether how one defines themselves – as a stand-alone individual or in terms of familial and group relationships – affects the neural representations of concepts of 'self', 'other', and a close family member. Individualism defines the self as a stand-alone unit, distinct from family and friends (Figure 4, bottom left panel a), while collectivism's defines the self in terms of one's family and friends (Figure 4, bottom left panel b). Markus and Kitayama (1991)[6] found that pattern of neural activation was very similar for 'self' and 'mother' in Chinese individuals, whereas the pattern for 'mother' appeared more like the pattern for 'other' in Western participants. The authors interpreted this to mean that collectivistic Chinese subjects consider their mothers to be part of their identity of themselves, whereas individualistic Westerners view the 'self' as distinct from any other person regardless of familial closeness.

To this point we have shown that cultural and early life experience affects behavior, perception and brain function, but there is also evidence that there could be an inherited, genetic component contributing to differences between collectivism and individualism.

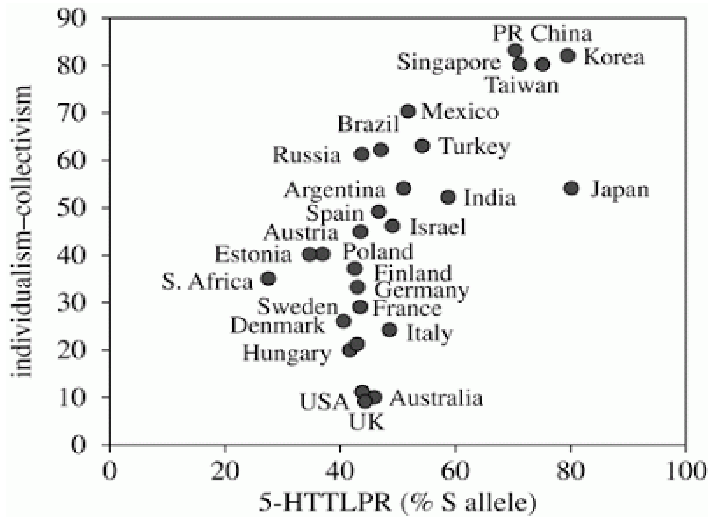


FIGURE 5: Frequency of the short variant of the serotonin transporter Gene (5-HTTLPR) is positively correlated with more collectivistic nations. From Chiao & Blizinsky, 2010.

In particular, the frequency a short version of the serotonin transporter gene (5-HTTLPR) is positively associated with collectivism.[7] Serotonin is a neurotransmitter in the brain involved in reward and emotional processes, and serotonin dysregulation is a mechanism behind some kinds of depression and anxiety disorders.[8] Because the short variant codes for a protein that clears serotonin from the brain more quickly than the

[6] Hazel R Markus and Shinobu Kitayama, "Culture and the Self: Implications for Cognition, Emotion, and Motivation.," *Psychological Review* 98, no. 2 (1991): 1–30.

[7] J C Barnes, Kevin M Beaver, and Brian B Boutwell, "A Functional Polymorphism in a Serotonin Transporter Gene (5-HTTLPR) Interacts with 9/11 to Predict Gun-Carrying Behavior," ed. Judith Homberg, *PLoS ONE* 8, no. 8 (August 28, 2013): e70807, doi:10.1371/journal.pone.0070807.t001; J Y Chiao and K D Blizinsky, "Culture-Gene Coevolution of Individualism-Collectivism and the Serotonin Transporter Gene," *Proceedings of the Royal Society B: Biological Sciences* 277, no. 1681 (January 11, 2010): 529–37, doi:10.1001/jama.1996.03540040037030.

[8] Serotonin reuptake inhibitors, better known as SSRIs, are antidepressants designed to increase the availability of serotonin in the brain.

long variant, it has been identified as a potential risk factor for depression, mood and anxiety disorders.

Studies have attempted to connect the 5-HTTPLR(s) to these psychological illnesses, but have had inconsistent findings. Additionally, if the short variant is a risk factor for psychological dysfunction, why do nations with higher frequency of short alleles within the population have lower incidence of anxiety and mood disorders? Additional analysis shows that individualism and collectivism is likely a mediating factor in predicting whether 5-HTTPLR(s) is a risk factor for anxiety disorders. When the degree of a nation's collectivism is considered, the explanatory power of 5-HTTPLR(s) status on the incidence of anxiety and mood disorders drops significantly, indicating the cultural factor - which is correlated with genetic distribution – explains national patterns in psychological disorders (Figure 6, bottom right panel).[9] The authors propose that interdependent social support of collectivistic societies prevents anxiety and mood disorders from developing, or that reporting psychological disorders is discouraged in closely-knit communities.

[9] ibid.

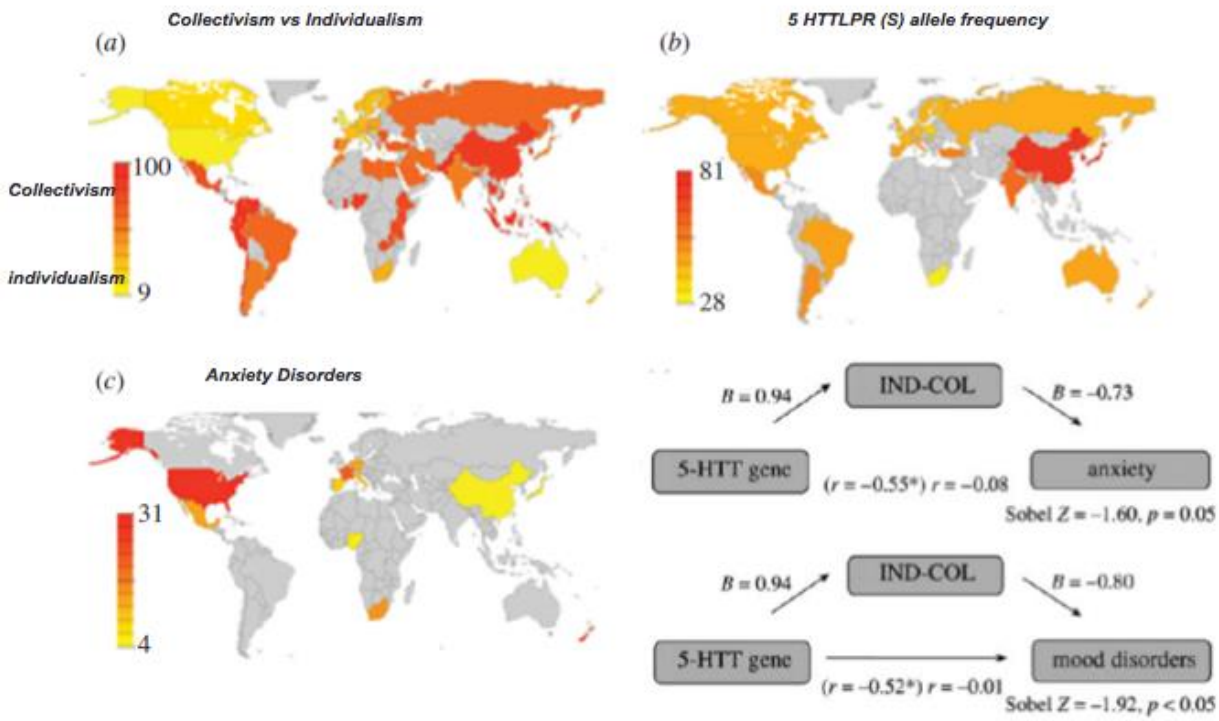


FIGURE 3: Relationship between individualism and collectivism, frequency of the short variant of the serotonin transporter, and incidence of anxiety disorders by country. Top Left: Distribution of collectivism and individualism across the globe. Top Right: Relative frequencies of the short variant of the serotonin transporter across the globe. Bottom Left: Incidence of anxiety disorders in reporting nations. Figure adapted from Chaio & Blizinsky, 2010.

The serotonin transporter gene has also been linked to Hofsteade's Power Distance Index (PDI), or measure of "the extent to which the less powerful members of organizations and institutions (like the family) accept and expect that power is distributed unequally (Figure 7)."[10] This finding implies the PDI is highly correlated or a subfunction of a society's collectivism. Most interesting for the purpose of considering military implications of neurocognitive differences, is that in independent cultures, those with power have a greater tendency to act assertively, whereas those in interdependent cultures show greater restraint with more power.

[10] Chen-Bo Zhong, Joe C. Magee, William W. Maddux, Adam D. Galinsky (2006), Power, Culture, and Action: Considerations in the Expression and Enactment of Power in East Asian and Western Societies, in Ya-Ru Chen (ed.) *National Culture and Groups (Research on Managing Groups and Teams, Volume 9)*, Emerald Group Publishing Limited, pp.53-73

Serotonin is not the only gene variant to be linked to cultural phenomena[11] and as such, some have considered whether the genes themselves has a role in developing the cultural preferences, or rather if cultural preferences for certain traits have had a hand in increasing the frequency of certain genes within a population. If culture has influenced genetic selection and allele distribution, then we may be able to identify more cultural and neurocognitive differences by examining which genes differ in frequency between populations.

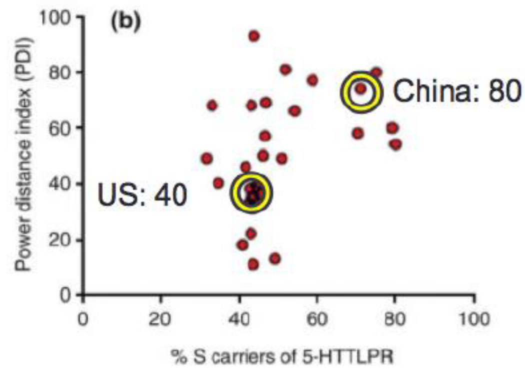


FIGURE 4: The relationship between a national Power Distance Index and frequency of the short version of the serotonin transporter gene (5-HTTLPR(s)). From Zhong, et al., 2006.

Gene-Culture Co-Evolutionary Theory. Chiao and Blizinsky believe that cultural preference can lead to genetic selection and have proposed the Gene Culture Co-evolutionary theory.[12] The theory postulates that once a trait becomes socially advantageous or desirable, that it will be selected for within a population. Over time and across

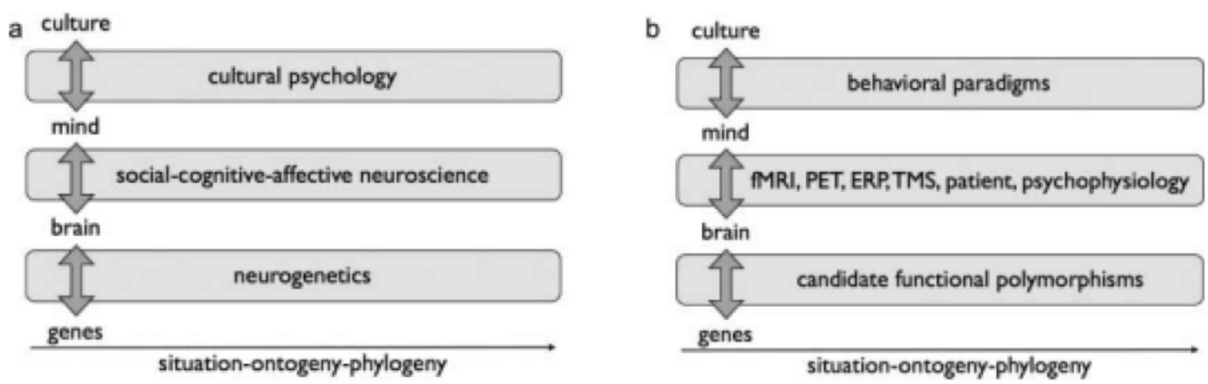


FIGURE 5: The relationship between neurogenetics, neuroscience and psychology as proposed by the Gene Culture Co-Evolutionary Theory. From Chaio, et al., 2013.

generations, genetic contributions to that trait should increase in frequency. In other words, collectivist societies may have over generations selected for collectivist traits such as the short variant of the serotonin transporter gene, thus increasing the frequency of short variants among the population.

[11] For instance, another gene (DRD4 7R+) is associated with both macro- (permanent continental migration, such as Europeans migrating to North America) and micro-migratory behavior (such as seasonal regional migration). This particular gene will be be considered later as the gene is also linked to risk taking behavior.

[12] "Culture-Gene Coevolution of Individualism-Collectivism and the Serotonin Transporter Gene" 277, no. 1681 (January 11, 2010): 529–37, doi:10.1098/rspb.2009.1650.

The theory's model (Figure 9) connects behavioral findings from cultural psychology, to neuroimaging results from cognitive neuroscience, to the potential genetic and epigenetic contributions to those phenotypes.[13] If Chiao's model is correct, we may be able to find other examples of divergent cognitive tendencies by identifying single nucleotide polymorphisms (SNPs) among genes that differ in frequency between populations of interest. Such information can never help us predict behavior or make assumptions about a population, but may highlight tendencies, proclivities or even types of cognitive bias of which we may currently not be aware. Though we currently know that Eastern and Western thought has distinct and profound differences, it is difficult to understand the true nature and depth of those differences. An added benefit of knowing what proteins may be involved is that it tells us something about the physiology behind those tendencies.

The devil is in the details. The challenge with examining genes, however, is that the more we study genetic data, the more we realize how little it tells us about what genes are actually expressed and how much that gene (if any) contributes to behavioral outcomes. We certainly cannot predict behavior at an individual level, but trends may arise across populations.

Our first clue to this limitation is how little the myriad studies linking *gene X* to *trait Y* have been able to tell us about the contribution of a single genetic variant to overall phenotypic variation. Studies often require *thousands* of subjects to obtain statistically significant results on highly controlled laboratory-administered tests and experiments, and attempted replications often generate null or even conflicting findings. Studies that look at how genes correlate with physiological function ('endophenotypes') such as emotional reactivity may have better luck finding consistent patterns in brain activity or in some other biomarker. These studies of endophenotypes are useful for identifying, for instance, areas of the brain most affected by a gene but they still have not contributed much more to link isolated genetic markers with behavior or even to psychological disorders.

> ***"Genes are rarely about inevitability, especially when it comes to humans, the brain and behavior. They're about vulnerability, propensities and tendencies."***
>
> ***– Robert Sapolsky***

[13] Joan Y Chiao et al., "Cultural Neuroscience: Progress and Promise," *Psychological Inquiry* 24, no. 1 (January 2013): 1–19, doi:10.1080/1047840X.2013.752715.

Sapolsky's comment is instructive. Having a gene does not mean one will exhibit an associated trait; rather it means they might have the potential to exhibit a trait depending on the influence of other (many thousands of) genes and of environmental factors. Moreover, any gene that has not been selected out of a population is likely to present no inherent disadvantage. Rather, and as we see with COMT(met/val) variants discussed later, one variant might be advantageous in a stressful context, whereas the other variant is advantageous in daily, non-stressful situations.

Although the genetic sequence is static, the expression of that sequence is dynamic and affected by more factors than we yet appreciate. Among the most well-known mechanisms that influence gene expression are **epistasis** and **epigenetics**.

Epistasis is the interaction among genes that affect their expression or magnitude of influence. As the cost of genetic sequencing has dropped, whole genome analyses and Genome Wide Association Studies (GWAS) have shown that there are often hundreds, if not thousands of genes that contribute to a single trait. For example, a study that examined over 15,000 people found 108 genetic contributions to schizophrenia (Figure 11).[14] There are even multiple variations within a single gene that can affect the function of a single brain receptor. As whole genome sequencing becomes cheaper and approaches the $1k/genome threshold, the hope among some researchers is that we may be better able to determine the complete set of genes that contribute to a given trait. At every turn, however, it seems scientists uncover new complexities and variables that affect and influence the pathway between the genetic code and the dynamic expression of that code. **Epigenetic influence,** for instance, is the environmental influence genetic trait expression, which can affect changes in a matter of hours, days, years or even lifetimes and generations.

[14] Stephan Ripke et al., "Biological Insights From 108 Schizophrenia-Associated Genetic Loci," *Nature* 511, no. 7510 (July 22, 2014): 421–27, doi:10.1038/nature13595.

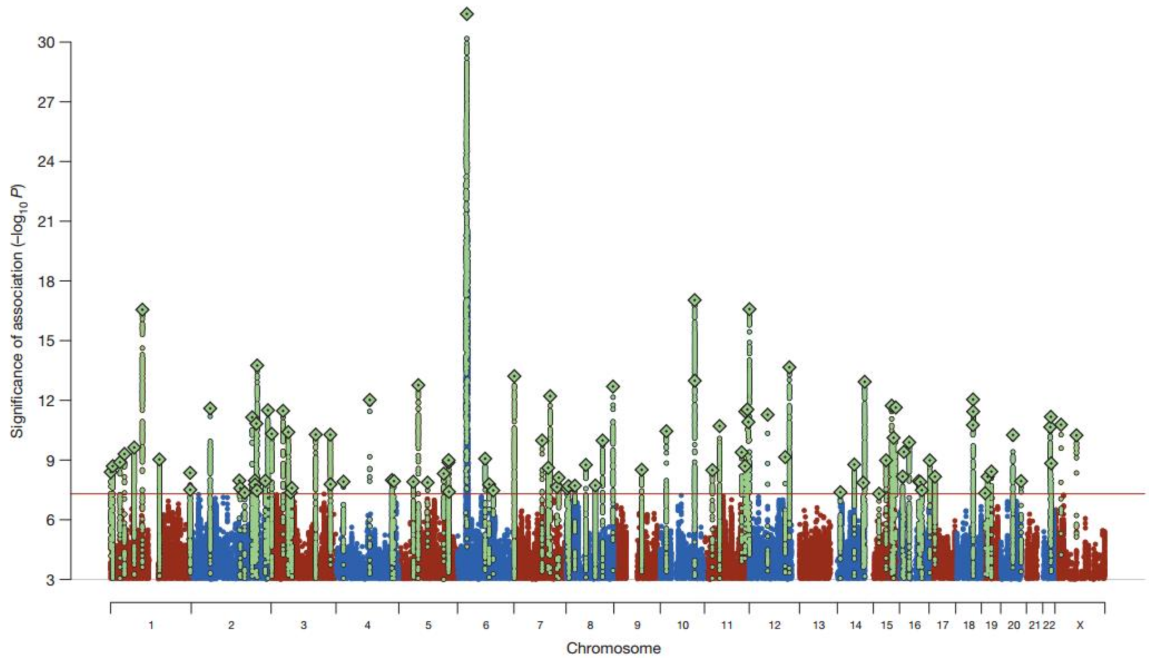


FIGURE 7: A Manhattan plot showing the 108 genes that showed significant associations with schizophrenia from a sample including more than 30,000 schizophrenics, and 40,000 healthy controls.. From Ripke, et al., 2014.

FIGURE 6: Dutch boy during the German-imposed food embargo on the Eastern Netherlands during World War II. From http://www.news.leiden.edu/news/dutch-hunger-winter.html

Just as experience and environment can influence brain development, it also affects which genes are expressed or 'mummified'. Epigenetic tags (methylation) determine if a gene is expressed. Just as the environment exposure changes brain function, it also influences which genes are expressed and in what situations. Certain genes are up-regulated and down-regulated in a daily or even hourly manner to support functions such memory formation, circadian rhythms, and metabolic sensitivity. There are also more permanent changes in which genes can be 'mummified' due to experiences that usually occur during critical stages in development. These epigenetic tags may even be passed down through generations, though the mechanism for inheritance is currently unclear. Notable examples come from the Dutch Famine Study that has looked at children and grandchildren of people who had been malnourished during the German-imposed food embargo on the Western Netherlands (the "Hunger Winter" of 1944-45). Children of mothers who were pregnant during the famine exhibited lower-than-typical methylation of a gene growth factor (IGF2).[15] Moreover, the *grandchildren* of men who lived during the famine have an elevated incidence of obesity and risk factors associated with metabolic disease.[16]

Some inconsistencies between studies attempting to link genes and behavior have been attributed to epigenetic differences among subjects. For example, and as was discussed above, there are links between the short variant of the serotonin transporter gene (5-HTTLPR(s)) and susceptibility to stress-induced depression and other stress-related disorders, but they are inconsistent.[17] Just as collectivism moderates the relationship between this gene's frequency and the incidence of anxiety disorders in a population, once researchers began to account for childhood trauma, the relationship between 5-HTTLPR(s) became more consistent.[18] It appears that early childhood trauma primes and programs the stress response system in a way that makes the short variant of the serotonin transporter gene a risk factor for psychological injury later in life.[19] In another very recent publication 4-way interactions between variants in BDNF, 5-HTTLPR, MAOA and various kinds of child-parent relationships (positive, conflicted and sexually abusive) predict outcomes of delinquency in a cohort of 1337 Swedish children.[20] The same genetic variants that were risk factors for delinquency in teenagers with negative parental relationships were associated with the lowest incidence of delinquency in teenagers with positive parental relationships. As complex as this study is, it still does not account for potential influence of individualistic value structures or whether interdependent social support structures might offset the harmful effects of abusive parenting, and based on the mediating influence of parental relationships, it is likely other social structures would also affect delinquency outcomes.

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[15] "Persistent Epigenetic Differences Associated with Prenatal Exposure to Famine in Humans" 105, no. 44 (November 4, 2008): 17046–49, doi:10.1073/pnas.0806560105.

[16] MVE Veenendaal et al., "Transgenerational Effects of Prenatal Exposure to the 1944-45 Dutch Famine," *BJOG: an International Journal of Obstetrics & Gynaecology* 120, no. 5 (January 24, 2013): 548–54, doi:10.1111/1471-0528.12136.

[17] Katja Karg et al., "The Serotonin Transporter Promoter Variant (5-HTTLPR), Stress, and Depression Meta-Analysis Revisited," *Archives of General Psychiatry* 68, no. 5 (May 2, 2011): 444, doi:10.1001/archgenpsychiatry.2010.189.

[18] Pingxing Xie et al., "Interactive Effect of Stressful Life Events and the Serotonin Transporter 5-HTTLPR Genotype on Posttraumatic Stress Disorder Diagnosis in 2 Independent Populations," *Archives of General Psychiatry* 66, no. 11 (November 1, 2009): 1201, doi:10.1001/archgenpsychiatry.2009.153.

[19] Luke W Hyde, Ryan Bogdan, and Ahmad R Hariri, "Understanding Risk Forpsychopathology Through Imaginggene," *Trends in Cognitive Sciences* 15, no. 9 (September 1, 2011): 417–27, doi:10.1016/j.tics.2011.07.001.

[20] K W Nilsson, E Comasco, and S Hodgins, "Genotypes Do Not Confer Risk for Delinquency but Rather Alter Susceptibility to Positive and Negative Environmental Factors: Gene-Environment Interactions of BDNF Val66Met, 5-HTTLPR, and MAOA-uVNTR," *International …*, 2014, 1–47, http://ijnp.oxfordjournals.org/content/ijnp/early/2014/12/09/ijnp.pyu107.full.pdf.

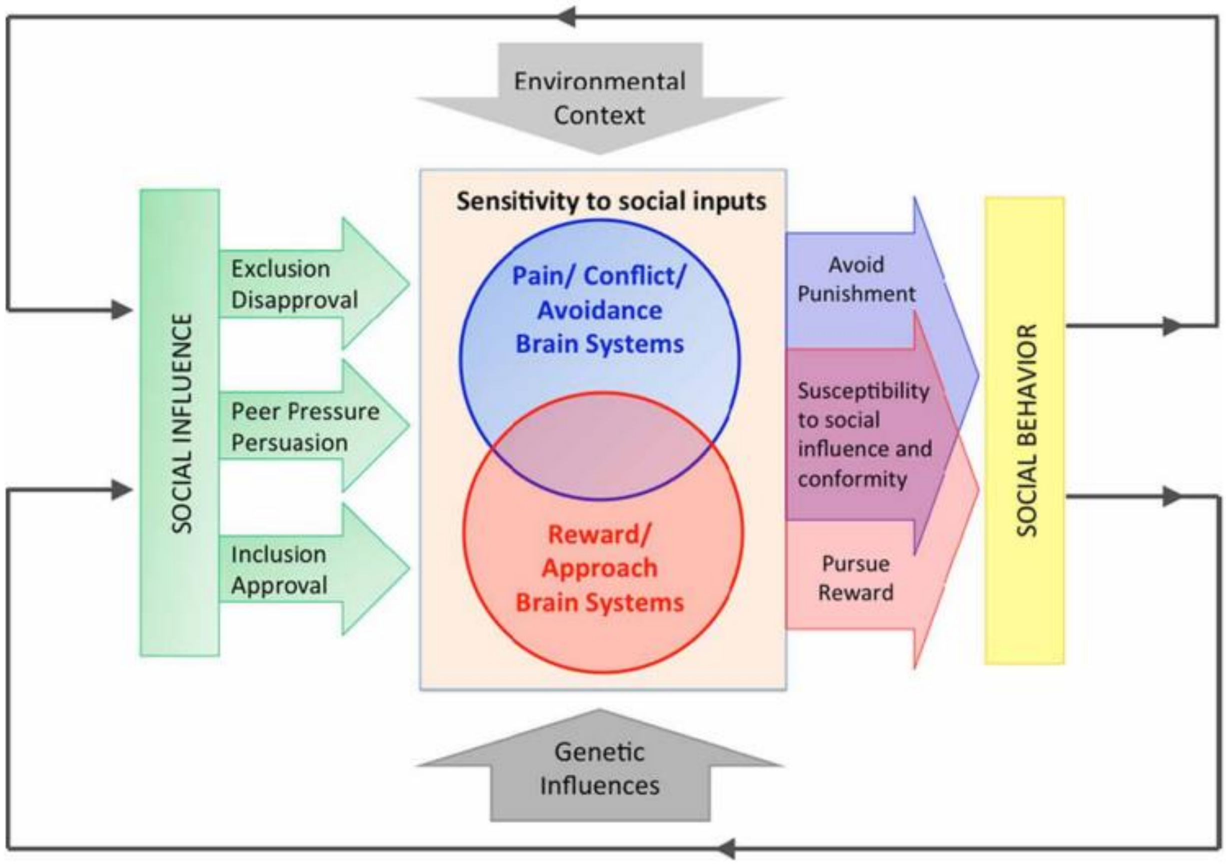

FIGURE 8: A model of social influence and behavior as a function of intrinsic motivations (i.e., pain avoidance and reward seeking), genetic, and environmental Influences. From Falk & Way (2012).

Though these two examples demonstrate how epigenetic mechanisms respond to trauma, the vast majority of epigenetic activity involves healthy regulatory processes. The time-courses of epigenetic influence range from tags that last lifetimes and generations, to tags that regulate circadian processes on a daily and even hourly basis.

Between gene-gene interactions and environmental interaction, the complexity of processes that regulate genetic expression and its response to the environment overwhelms our current theoretical understanding and experimental analytical tools. The complexity of one's social world and interactions that influence these regulatory processes add an additional layer of complexity (Figure 11)[21] Falk, Way & Jasinska (2012) that summarizes Simple gene/trait association studies are falling by the wayside in favor of more comprehensive methods, such as GWAS, but even large databases pooling human genetic data cannot account for the many

[21] Emily B Falk and Baldwin M Way, "An Imaging Genetics Approach to Understanding Social Influence," June 8, 2012, 1–13, doi:10.3389/fnhum.2012.00168/abstract.

regulatory dynamics between the presence of a genetic variant and behavioral outcomes. A small benefit of looking at genetic distributions is that, even if we cannot predict trait outcomes from genetic code, clusters of genes that interact with phenomenon can point us towards neuroanatomical systems and mechanisms. If we understand what neuroanatomy is involved, we can begin to make educated guesses about how differences may influence cognitive processes, and then think about where we can find evidence to support or refute those guesses.

A FRAMEWORK FOR THINKING ABOUT THE NEUROCOGNITIVE DIFFERENCES

Because these issues are complex and can appear tautological in nature, we turn to David Marr's analytical framework for understanding different levels of neural computation to help organize our analysis of the military implications of neurocognitive differences between Eastern and Western populations. Fundamental to the questions posed by this report and the findings of cultural neuroscience in general, is consideration is *how* neurocognitive function differs among populations. Marr postulates that there are three major levels for scientific inquiry of neural function that should not be confused: 1) **the computational level, goal** or problem the computation is trying to solve; 2) **the representation (inputs/outputs) and algorithm** or strategy employed to solve the problem; and 3) t**he physical implementation** or hardware responsible for executing the algorithm. It is apparent that cultural differences between Eastern and Western thought are due in part to different goals based on divergence in motivations. For instance, the [redacted] view of an acceptable military outcome is often defined in relative terms (did the event result in even a small improvement in [redacted] positioning?) whereas the US military's measures of success are absolute (were pre-defined mission objectives achieved?). Thus, cultural differences in motivation and definitions of what is desirable affect the computational level of analysis. Neurocognitive differences, on the other hand, affect the representations and algorithms used to achieve those goals. For instance, whether a commander interprets a question as a threat (representation), would subsequently dictate which brain structures and chemicals (physical implementation) are recruited to process that threat. Thus, cultural differences most affect goals (Marr's first level), neurocognitive differences most likely affect the computational strategies (Marr's second level), and neither changes the quality or integrity of the physical neural hardware which is why threats are computed similarly (flight or fight) and with the same hardware (amygdala, norepinephrine) in any culture.

Applying Marr's levels to the challenge of understanding the nature, and extent of culturally divergent cognitive styles is both useful and important for two reasons:

1. It helps bound the ways in which cognitive styles are likely to differ, and in which ways they do not; and

2. It should quiet some of the misunderstandings surrounding cultural neuroscience. Computers can run different algorithms, each with strengths and weaknesses depending on the goal, but the choice of algorithm does not reflect the quality of the hardware used to implement the algorithm. Just as there are strengths and weaknesses associated with every algorithm depending on the problem at hand, so too might there be of cognitive styles. But like the computer it does not mean the brains in question are substantively different in structure and function.

Additionally, Marr's levels of scientific inquiry help us put into perspective the potential military implications of understanding those neurocognitive styles. [redacted] It is the author's opinion that neurocognitive differences may *shade* strategies, approaches, reactions and outcomes but are far less influential than the cultural influences on strategic planning and goal setting. This means that traditional study of cultures, motivations, and socioeconomic pressures will tell us far more than the subtle ways culture may influence neural computations. Moreover, because we currently understand such a small portion of overall brain function, the small body of neurocultural research provides scant ability to project and anticipate behavior. These limitations are important to keep in mind as we consider and the ways in which different neurocognitive factors may interact with performance disruptors (i.e., fatigue, stress, etc.) and influence military scenarios throughout the rest of the report.

Understanding neurocognitive differences may instead be most useful for helping us consider and overcome our own analytic pitfalls such as mirror-imaging, the fundamental attribution error and cognitive biases when we consider the most salient motivations and drivers of others. There is also evidence that diverse cultural thinking styles and alternate perspectives foster innovation and promote complex problem solving even beyond that which comes with diversity in expertise. Scientific papers authored by a more ethnically diverse group were cited more frequency and had more relative impact than those authored by an ethnically homogenous group. [22] This means that the more we consider different ways others perceive and react to the world can enrich our own innovative processes.

[22] Phillips, "How Diversity Makes Us Smarter."

3. Performance Disruptors

Part of considering the potential military implications of neurocognitive differences between populations requires we also consider the contexts in which operators perform. Rarely do units or commanders operate in the well-controlled, relatively stress free environment of a university research laboratory. Operational scenarios and unit demands vary tremendously depending on service, mission, and environment yet certain pressures are common (such as acute and chronic stress) and in some cases almost universal (fatigue or sleep deprivation) across the military. These pressures also interact with neurocognitive mechanisms. We will refer to these pressures as "Performance Disruptors" because they pose physiological challenges to optimal performance states and influence homeostatic mechanisms with cognitive consequences. [23]

The disruptors we will consider in the below discussion include:

- **Fatigue** including acute sleep deprivation and chronic sleep restriction.
- **Boredom/monotony** in tasks or missions that require persistent and sustained vigilance.
- **Acute stress** such as that experienced during a firefight or an encounter with a roadside improvised explosive device (IED).
- **Chronic stress** such as that which comes with extended deployments, high operational tempo units, or even that experienced by Remotely Piloted Vehicle pilots who must balance the demands of combat operations and home life at the same time. **Chronic uncontrollable stress** is a particularly damaging type of chronic stress that can be the result of extended deployments, or the constant nagging worry of impending threat from random mortar attacks or hidden roadside IEDs.

The disruptors that are common amongst civilian populations as well as in militaries have also been the subject of extensive research from which we can base our analysis. For instance, fatigue and sleep deprivation is of major interest to trucking communities and the United States Department of Transportation (USDOT) and chronic stress is an ongoing challenge for end-of-life caregivers and hospital workers of various kinds. The physiological, hormonal and neurochemical effects of these disruptors have been linked to changes in cognition, behavior

[23] Sometimes these stressors can lead to an improvement of performance depending on the performer's initial state. For instance, a small amount of stress can increase one's attentiveness during a monotonous task. We will use the term 'disruptor' in its generic sense in that the pressure shifts or disrupts the baseline state.

and job performance. We can use this research to speculate as to how the change interacts with neurocognitive differences. For instance, if such studies show fatigued individuals are more susceptible to cognitive bias, are Westerners more likely to emphasize objects and Easterners more likely to emphasize contexts when fatigued? Table 1 summarizes overarching neurocognitive effects of these performance disruptors.

TABLE 1: Neurophysiological chemical and cognitive behavioral effects to performance disruptors

PHYSIOLOGICAL EFFECTS	COGNITIVE BEHAVIORAL EFFECTS ON INFORMATION PROCESSING
Acute Stress • **Increased catecholamine release (Dopamine, Norepinephrine) in the brain** • **Increased autonomic arousal increases adrenaline in the periphery**	***Perception.*** "Tunnel vision". Acute stress limits information intake. Culturally salient cues are more likely to be processed during acute stress. ***Interpretation.*** Hyper-reactive and more likely to interpret ambiguous information as threatening. ***Reaction/Action & Decision Making.*** Fight/flight/freeze. Actions favor habitual responses. Fine motor function deteriorates (shaky hands).
Chronic Stress • **Impaired memory** • **Hormonal dysregulation and inability to mount a protective hormonal response to acute stressors.** • **Weight gain, cardiovascular risks**	***Perception***. Indiscriminant hyper-vigilance to threatening and non-threatening stimuli ***Interpretation***. Impairs long-term memory formation undermining the ability to update situational awareness and learn. ***Reaction/Action & Decision Making.*** Hyper-reactive to non-threatening stimuli; hypo-reactive to threatening stimuli
Fatigue • **Exercise fatigue – decreased dopamine** • **Increased serotonin** • **Sleep deprivation increases striatal DA to maintain wakefulness (DAT1) but not DA to problem-solving, decision-making areas**	***Perception.*** Missed signals, and undermined ability to detect novel meaningful patterns. ***Interpretation***. Limits abstract thinking and the generation of alternative interpretations and hypotheses. ***Reaction/Action & Decision Making.*** Slows reaction time and decreases accuracy. Wakefulness is maintained at the expense of complex executive function ("zombie-like" behavior).
Boredom/Monotony • **Low stimulation of executive brain areas; low DA availability** • **Drowsiness, especially if also sleep deprived**	***Perception.*** Inattention and inability to focus leads to missed signals and limits information processing ***Interpretation.*** When watching for rare events, can increase both false alarms and false negatives. ***Reaction/Action & Decision Making***. Absence of reaction/response; slow reaction times to detected events

FATIGUE, SLEEP DEPRIVATION AND SLEEP RESTRICTION.

Sleep deprivation and sleep restriction are constant problems for [redacted], it is almost certain sleep deprivation and sleep restriction are common problems for all militaries during ongoing and active operations. In this section we will review the different kinds of sleep deprivation and the cognitive and operational effects of lack of sleep before discussing interactions with divergent neurocognitive and cultural factors.

SLEEP DEPRIVATION VERSUS SLEEP RESTRICTION. While the term 'sleep deprivation' is often used to describe all types of lack of sleep, it is important to distinguish between continuous, sustained wakefulness with no sleep, and consecutive days, weeks or months of very little sleep per night.

- **Total sleep deprivation** – Sustained wakefulness beyond a typical 16-hour day. Most sleep deprivation studies use total sleep deprivation paradigms that extend for 24-48 hours.
- **Sleep restriction** – Or 'Chronic Partial Sleep Restriction' consists of days, weeks, or months in which an individual gets fewer than 5-6 hours of sleep per night. Fewer studies have mimicked this type of sleep deprivation, but it is far more common pattern across military communities.

Operators suffer sleep deprivation while executing multi-day kinetic missions (e.g., long-range bombing sorties, direct action, special reconnaissance, etc), particularly intense training ([redacted]), and selection courses (e.g., [redacted]). Some Concepts of Operations (CONOPS), including [redacted], rely on an operator's ability stay awake throughout the majority of a multi-day operation. B-2 crews can take shifted naps during flight, but most report not sleeping more than a few isolated minutes if at all.[24]

Sleep restriction is far more common than total sleep deprivation and almost ubiquitous throughout the US military, regardless of service, mission or role. This is especially true during high operational tempo (OPTEMPO) periods of deployment; as OPTEMPO increases, sleep per night among [redacted] This is not just a problem in the [redacted] Table 2

[24] AH Russell, BA Bulkley, C Grafton. Human Performance Enhancement, Military Mission Skills Report. Office of the Secretary of Defense, Net Assessment. 2004.

[25] "[redacted]

shows that more than half of all personnel across a [redacted], regardless of deployment schedules.

Characteristic/Group	Average Hours of Sleep in Past 6 Months[c]			
	2 Hours or Less	3 or 4 Hours	5 or 6 Hours	7 Hours or More
[redacted]	2.1 (0.4)[4]	17.9 (1.3)[234]	60.1 (1.0)[4]	20.0 (0.8)[4]
	2.1 (0.5)[4]	13.7 (0.9)[14]	62.5 (1.4)[4]	21.7 (2.0)[4]
	2.1 (0.4)[4]	13.9 (1.1)[14]	60.6 (1.0)[4]	23.4 (1.7)[4]
	0.5 (0.1)[123]	8.1 (0.6)[123]	57.2 (0.5)[123]	34.2 (0.8)[123]

TABLE 2: [redacted]

Self-assessments of fatigue-related cognitive impairment are notoriously poor. Service members often report that they either get used to working well on 4-5 hours of sleep per night, or that they "only really need" 4-5 hours of sleep to be effective.[27] Cognitive testing shows otherwise; performance decrements after two weeks of sleeping 4 hours per night is similar to two nights of total sleep deprivation.[28]

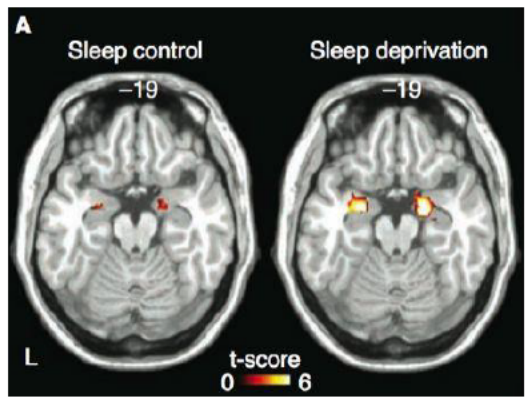

Figure 9: exaggerated activity in the amygdala after a bout of sleep deprivation. From Dinges, 2005.

Sleep recovery after deployment is also at risk. Combat exposed and redeployed operators have an increased risk of insomnia or chronic 'short sleep duration' that affects duties as well as and overall health and well-being.[29,30] Some researchers have proposed that lack of sleep may even make people more vulnerable to trauma-related psychological injury such as Post Traumatic Stress Disorder (PTSD).[31]

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26 "Department of Defense Survey of Health Related Behaviors Among Active Duty Military Personnel," January 1, 2009, http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA527178.
27 AH Russell, BA Bulkley, C Grafton. Human Performance Enhancement, Military Mission Skills Report. Office of the Secretary of Defense, Net Assessment. 2004.
28 Namni Goel et al., "Neurocognitive Consequences of Sleep Deprivation.," *Seminars in Neurology* 29, no. 4 (September 2009): 320–39, doi:10.1055/s-0029-1237117.
29 "Sleep Patterns Before, During, and After Deployment to Iraq and Afghanistan," November 4, 2010, 1–12.
30 "Prevalence and Impact of Short Sleep Duration in Redeployed OIF Soldiers," January 1, 2011, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3157660/.
31 Seth Robbins, "Seeking Better Sleep," *Stars and Stripes*, February 5, 2011, http://www.stripes.com/seeking-better-sleep-1.133924.

Cognitive effects of sleep deprivation. Though many have and do perform under sleep-deprived conditions, the evidence is irrefutable that sleep deprivation impairs performance by compromising cognitive function. All sleep-deprived humans are less vigilant, are slower to respond, commit more errors, exhibit less inhibitory control and have diminished capacity for abstract thought than when they are well rested. Sleep deprivation also limits divergent thinking, creative problem solving and interferes with memory formation.[32] Sleep deprived people are also more likely to revert to habitual behaviors ([redacted]) and are more susceptible to cognitive bias. See Table 3 for a summary of the cognitive effects of sleep deprivation (adapted from Drumer & Dinges, 2005) [redacted]

[redacted]

[redacted] Goel et al., "Neurocognitive Consequences of Sleep Deprivation.," *Seminars in Neurology* 29, no. 4 (September 2009): 320–39, doi:10.1055/s-0029-1237117.

[33] Negative regression is the tendency to revert to old habits when either stressed or fatigued. For example, if the same control is located in a different location in a new platform, [redacted].

TABLE 3: Cognitive an operational effects of sleep deprivation and sleep restriction.

Cognitive Performance Effects of Sleep Deprivation ***List adapted from Durmer & Dinges, 2005[34]***	**Impact on Operations**
• *Involuntary microsleeps* • *Attention-intensive performance is unstable with increased errors of omission (missed signals) & commission (false alarms); increased susceptibility to false memories[35]* • *Self-paced tasks slow; time pressure increases cognitive errors* • *Slower response times* • *Short term & working memory declines* • *Reduced learning/ skill acquisition* • *Performance requiring divergent thinking deteriorates* • *Errors inhibiting responses increase* • *Increased perseveration (waffling)* • *Increased effort to compensate for performance decrements* • *Performance in lengthy tasks deteriorates more quickly* • *Loss of situational awareness; reduced ability to multitask; increased neglect for less-essential tasks/information* • *Exaggerated threat response (see Figure 12)* • *Impaired visuomotor performance and spatial attention*	• [redacted]

Military field research shows sleep deprivation affects mission-essential skills in various unit types. For instance, in one study the marksmanship accuracy among [redacted] dropped significantly after 73 hours of sleep deprivation; they missed 37% more targets, increased the distance of shots from the center of mass by 38%, and took 53% longer to sight each target.[36] Since marksmanship is a perishable skill set and sleep impairs memory formation, operators

[34] Goel et al., "Neurocognitive Consequences of Sleep Deprivation."

[35] S J Frenda et al., "Sleep Deprivation and False Memories," *Psychological Science*, July 16, 2014, doi:10.1177/0956797614534694.

[36] William J Tharion, Barbara Shukitt-Hale, and Harris R Lieberman, "Caffeine Effects on Marksmanship During High-Stress Military Training with 72 Hour Sleep Deprivation.," *Aviation, Space, and Environmental Medicine* 74, no. 4 (April 2003): 309–14.

would also have to spend more time training and re-training under sleep deprived conditions to pass periodic qualification tests, imposing time and financial burdens. Likewise, error rates in [redacted] significantly increased on 19 of 29 evaluation metrics over the course of a 38-hour simulation.[37] These metrics included maneuvers such as the [redacted]

A study from the early 1980s found sleep deprivation affected the rigor and efficiency of team performance.[38] Over the course of a 36-hour continuous [redacted] direction center simulation, the rigor with which the unit adhered to standard tactics, techniques and procedures eroded. Near the end of the simulation, the units did not update their situation map as frequently, and were not as consistent in computing their [redacted] ahead of the time they would need to execute fire. Early in the simulation the team was able to efficiently simulate [redacted]s immediately. Beyond 24 hours the unit became disorganized and confused trying to plot [redacted], and executed only after extended delays. While there are other examples in which unit and team presence lessened the effect of individual sleep deprivation,[39] there is still an overall negative net impact on team as well as individual performance.

A number of operational missteps with lethal outcomes have been attributed to sleep deprivation. [redacted]

[37] Hans P A Van Dongen, John A Caldwell, and J Lynn Caldwell, "Investigating Systematic Individual Differences in Sleep-Deprived Performance on a High-Fidelity Flight Simulator," *Behavior Research Methods* 38, no. 2 (May 2006): 333–43.

[38] L.E. Bandaret, JW Stokes, R Francesconi, DM Kowal, and P Naitoh, 1981. "Artillery teams in sustained combat: Performance and other measures". *The Twenty-Four Hour Workday: Proceedings of a Symposium on Variations in Work-Sleep Schedules.* Department of Health and Human Services (DHHS) National Institute for Occupational Safety and Health, Report 81-127, Pp 581-604

[39] Joseph V Baranski et al., "Effects of Sleep Loss on Team Decision Making: Motivational Loss or Motivational Gain?," *Human Factors: the Journal of the Human Factors and Ergonomics Society* 49, no. 4 (August 1, 2007): 646–60, doi:10.1518/001872007X215728.

[40] "Cognitive Sequelae of Sustained Operations," (New York: Springer Publishing Company, LLC, 2010), 321–60, http://books.google.com/books?hl=en&lr=&id=Un6eG0_JF2IC&oi=fnd&pg=PA297&dq=Cognitive+Sequelae+of+sustained+operations&ots=taiyUaBYwx&sig=qtbxUeE_jS_8vNUL_YziBx0nODM.

It is clear that sleep deprivation impairs performance by degrading cognitive function, but it is less clear whether cultural differences in value placed on sleep, regional sleeping behaviors, and various genetic differences in cognitive systems are affected by sleep deprivation.

CULTURAL FACTORS INTERACTING WITH SLEEP DEPRIVATION.

> ***In the morning get up at the hour of the rabbit, in the evening go to bed at the hour of the rat.***
>
> ***- Quoted in Kurokawa 2/1977:22*** [41]

In general, Americans and Westerners tend to associate extended sleep with laziness, illness or weakness and as a detractor from productivity. Though much of the rest of the world has similar associations of sleep *in excess*, Americans and Northwestern Europeans tend to have the most extreme views in this regard. The [redacted] have an equivalent to the siesta, known as the [redacted] and the [redacted] government went as far as to legally regulate sleep by including an explicit "right to rest" for workers in the [redacted] constitution.[42] The contrast between Eastern and Western approaches to work/sleep balance is sometimes stark, as is illustrated by the below quote from Steger & Brunt's study of Eastern sleeping behavior.

> ***"...an American engineer visited an oil rig in the South China Sea, which was equipped with what at the time was probably state-of-the-art technology. To his surprise, all the Chinese workers turned off the machines at noon and went off for lunch, followed by a nap, or xiuxi as they call it. This American engineer commented that this practice was unthinkable in the West, for precious machines like this must run twenty-four hours a day to maximise efficiency and profit. "***
>
> ***Steger & Brunt[43] (p. 48)***

This is not to say that Eastern societies are inherently sleep-loving; Confucian thinking characterizes sleep as a necessary indulgence that, like food, needs to be controlled. Just as in

[41] Brigitte Steger and Lodewijk Brunt, "Night-Time and Sleep in Asia and the West," September 29, 2005, 1–250.
[42] ibid.
[43] ibid.

the West, there are current and on-going debates in Japan and China as to whether to reject or embrace mid-day napping as a contributor to, or detractor from productivity.[44,45] All taken together, however, North Western populations deprioritize the value of sleep compared to the value of extra work hours far more than in the South or East. The result is that Westerners societies are more sleep-deprived on average than the rest of the world.

Individualistic Western values may further contribute to sleep-deprivation among US commanders. Many US commanders will voluntarily sacrifice sleep during an operation because they believe the benefit they provide to their unit during the course of operations outweighs any fatigue-related cognitive decrements (humans are also notoriously bad at recognizing their own fatigue-related impairment[46]). If a commander feels an individual responsibility to make decisions that affect a whole unit, that commander will feel a greater obligation to be present during all ongoing operations. If in the [redacted], decisions are collective and do not rely as heavily on individuals, commanders may be willing to sleep more often or for longer hours at a time.

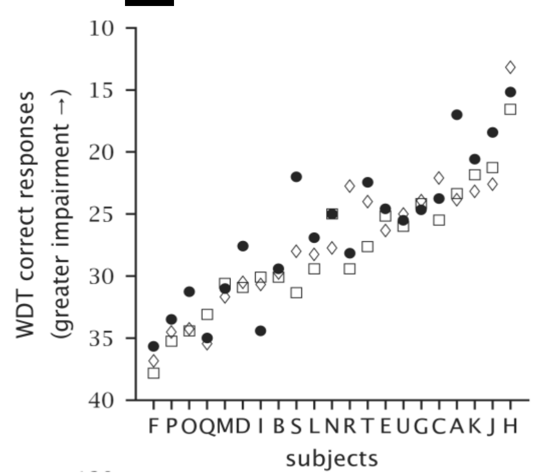

FIGURE 10: Individuals show consistency in their level of post-sleep deprivation impairment. Each of the subjects listed on the X-axis were tested on three separate occasions on a battery of tests (including a word detection task, or WDT). Each symbol represents a different testing day. From Dongen & Baynard, 2004.

As mentioned above, people may also behave in a more culturally-congruent manner under sleep-deprived conditions since people tend to revert to habits and heuristics when fatigued. Those from individualistic cultures may show greater object bias or a greater sense of agency, for instance, when fatigued than when rested, while collectivists may show opposite patterns. Priming studies suggest that cultural cues can induce culturally-typical behaviors in bi-cultural individuals who will endorse Western values when primed with Western cues, and endorse Eastern values when primed with Eastern cues. Nationalism within a county often surges during wartime, which may increase conscious preference for regional value structures, heuristics and behaviors. Together this suggests that during times of war and conflict, when sleep deprivation and nationalism are

44 ibid.

45 Interestingly, opinions on napping among the Chinese tend to align with positive or negative views of Western cultural influence on Eastern life in a globalized economy; those who embrace Western culture tend to reject napping while those who reject Western influence are more likely to embrace *xiuxi*

46 JV Baranski, RA Pigeau, and RG Angus, "On the Ability to Self-Monitor Cognitive Performance During Sleep Deprivation: a Calibration Study.," *Journal of Sleep Research* 3, no. 1 (March 1994): 36–44.

both high, we might expect people to show both conscious and subconscious preference for cultural congruence.

GENETIC FACTORS INTERACTING WITH SLEEP DEPRIVATION

Though everyone suffers performance decrements with sleep deprivation, not everyone is equally susceptible to sleep deprivation. While all of the [redacted] became degraded over the course of the aforementioned simulation some were compromised significantly more than others. Individuals were also remarkably consistent in their level of performance decrement over three separate bouts of 36-hour total sleep deprivation (see Figure 14), which suggests trait-like patterns in fatigue-related impairment.[47] Variation in duration and sleep-wake habits are also heritable (~30%) suggesting that there may be a genetic contribution to sensitivity to sleep deprivation. Despite a good deal of research on the genetics of sleep deprivation, is not clear what contributes to these individual patterns of resistance to sleep disturbances.

There is more evidence, however, for genetic contributions to sensitivity to shifting sleep schedules. The majority of genetic sleep research in humans has focused on sleep patterns. A number of 'clock' variants (including *Clock*, *Per2*, *Per3*, and *Bmal1*) have been associated with sleep patterns and influence whether someone is predisposed to be a night owl or an early bird. The distribution of these genes and combinations of these genes (haplotypes) differ among regional populations (Han, American European, Papua New Guinean),[48] but have not been associated with sleeping patterns between Eastern and Western groups. Rather, most regional differences in sleeping patterns and circadian rhythms[49] are associated with geographic distance either North or South of the equator and involve adjustments to light/dark cycles rather than absolute sleep requirements. This may mean Northern populations are be better suited to adjusting to altered sleep and wake cycles compared to Southern populations, but there is no indication if such patterns exist nor if such adaptability is learned at an early age in development. Regardless of cultural or genetic contributions, Western power-projection makes US forces more susceptible to the influence of shifted sleep schedules than Eastern groups. High-demand, high-OPTMEPO units in particular regularly cross twelve hours of time zones with little time for adjustment before a mission, and operate at predominantly at night reversing the natural sleep-wake cycle. [redacted] special forces may also plan to operate at night, but most [redacted]

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[47] H Cousijn et al., "Acute Stress Modulates Genotype Effects on Amygdala Processing in Humans," *Proceedings of the National Academy of Sciences* 107, no. 21 (May 25, 2010): 9867–72, doi:10.1073/pnas.1003514107.

[48] Mario Pedrazzoli et al., "Interactions of Polymorphisms in Different Clock Genes Associated with Circadian Phenotypes in Humans.," *Genetics and Molecular Biology* 33, no. 4 (October 2010): 627–32, doi:10.1590/S1415-47572010005000092.

[49] Cathy A Wyse, "Does Human Evolution in Different Latitudes Influence Susceptibility to Obesity via the Circadian Pacemaker?," *BioEssays* 34, no. 11 (August 30, 2012): 921–24, doi:10.1002/bies.201200067.

scholars agree that the [redacted]

A Japanese lab has created an "un-jetlaggable" mouse using genetic modification,[51] and though is not clear how similar humans and mice are in this regard (mice are nocturnal, so they likely differ considerably), nor whether there are variants for the human circadian systems, this kind of finding could guide the development of pharmaceutical treatments for jet lag.

Physiology. In response to sleep restriction and deprivation the body increases dopamine release in central brain structures to maintain wakefulness and other basic cognitive functions. There does not seem to be the same increase in dopamine in the frontal cortex, however, which is responsible for executive cognitive functions such as complex decision-making and problem solving, inhibitory impulse and emotion control, attention control, and learning and skill acquisition. As a result, all of these executive functions deteriorate with sleep restriction and deprivation. One of the few studies that has examined genetic susceptibility to cognitive deficits associated with sleep deprivation found COMT(met) carriers – who have more residual dopamine in the frontal executive areas– do not show the same advantage after sleep deprivation.[52]

COMT also influence the effectiveness of two stimulants for offsetting the effects of sleep deprivation; amphetamine and modafinil. [redacted]

Amphetamines work by blocking the reuptake of monoamine neurotransmitters – including dopamine and norepinephrine – which are cleared by the COMT enzyme. COMT(val/val) carriers with a high active version of the COMT enzyme show improved performance after taking amphetamine compared to baseline. Those with the low-active version of COMT(met/met) show no benefit from amphetamine on simple tasks, and actually perform worse on high cognitive-load tasks.[53] This suggests that amphetamine pushes monoamine levels to an optimal level in COMT(val/val) carriers, but levels become too high in COMT(met/met) carriers stimulating frontal executive regions. Modafinil, a drug developed to treat narcolepsy, improved both perception of wakefulness and helped offset decrements in

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[50] Participant, NeuroCognitive Divide Workshop. Scitor Corporation, Rosslyn Virginia, 3 June,2014.

[51] Y Yamaguchi et al., "Mice Genetically Deficient in Vasopressin V1a and V1b Receptors Are Resistant to Jet Lag," *Science* 342, no. 6154 (October 3, 2013): 85–90, doi:10.1126/science.1238599.

[52] Namni Goel et al., "Catechol-O-Methyltransferase Val158Met Polymorphism Associates with Individual Differences in Sleep Physiologic Responses to Chronic Sleep Loss," ed. Monica Uddin, *PLoS ONE* 6, no. 12 (December 27, 2011): e29283, doi:10.1371/journal.pone.0029283.t002.

[53] Venkata S Mattay et al., "Catechol O-Methyltransferase Val158-Met Genotype and Individual Variation in the Brain Response to Amphetamine," *Proceedings of the National Academy of Sciences of the United States of America* 100, no. 10 (2003): 6186–91.

executive function and vigilance in those with COMT(val/val) genotypes but had little effect on COMT(met/met) homozygotes.[54] Because the *val* allele is more prevalent in Western (48%) compared to Eastern populations (25-29%), Western militaries might benefit to a greater degree from using these stimulants during extended operations and other sleep-deprived situations.

[redacted]

This may change as more physicians genetically type individuals to guide prescriptions, as is already done with warfarin (a blood thinner) dosages. If COMT status is not as predictive and reliable for determining amphetamine sensitivity as genetic typing is for warfarin sensitivity, the Western faith in scientific evidence and individualized medicine may outweigh cultural resistance against using those chemicals in combat.

Caffeine, on the other hand, is widely accepted and used throughout the US military – whether taken in the form of coffee, energy drinks (Red Bull, Monster and Rockstar), or pills (No-Doz, Ripped Fuel) – but it provides selective benefits. Studies show that caffeine improves and sustains performance on tasks associated with major motor movements but not on those involving finely tuned-skills. Caffeine helped reduce the time [redacted] took to sight targets but did not offset the shot accuracy decrements associated with 72 hours of sleep

[54] S Bodenmann et al., "Pharmacogenetics of Modafinil After Sleep Loss: Catechol-O-Methyltransferase Genotype Modulates Waking Functions but Not Recovery Sleep," *Clinical Pharmacology & Therapeutics* 85, no. 3 (November 26, 2008): 296–304, doi:10.1038/clpt.2008.222.

[55] Moreno, Jonathan. "Stay Awake, Comrades" *Psychology Today* (2012) http://www.psychologytoday.com/blog/mind-wars/201204/stay-awake-comrades

deprivation.[56] Other findings indicate that caffeine may help with generalized arousal deficits but not those associated with executive functions such as problem solving and divergent thinking.

Just as with modafinil, some may be more sensitive to caffeine than others as few genetic variants have been linked to caffeine sensitivity or adverse effects of caffeine (see Table 4 below). The population differences between the East and West are small, but taken as a collective suggest that Eastern populations may be slightly more prone to some of the adverse effects of caffeine (such as anxiety, sleep disruption and risk of heart attack) compared to Western populations. [57] Militarily this suggests that the US may incur less risk from using caffeine to offset some of the effects of sleep deprivation.

TABLE 4: Genetic interactions with caffeine.

Genetic Variant	Interaction with Caffeine	Population Frequencies	Implications
CYP1A2 (C→ A)	A is faster to catabolize caffeine. Increased sensitivity to caffeine among smokers[58]	**CYP1A2(A)** European: 72% Han: 67% Japanese: 59%	Western populations might have a slightly higher incidence of caffeine sensitivity compared to Eastern populations.
ADORA2A (C/T)	C/C genotype more sensitive to caffeine T/T greater caffeine-induced anxiety[59]	**ADORA2A(C)** European: 54-66% Han: 53% Japanese: 56%	Eastern populations may on average be slightly less sensitive to the benefits of caffeine and prone to the anxiogenic effects of caffeine than Western populations
DRD2 (7R+)	Greater caffeine-induced anxiety.[60]	No data available	--
COMT (Val158Met)	COMT(met) have higher risk of myocardial	**COMT(met)** European: 52%	Eastern populations incur greater risk from using caffeine to offset

[56] Tharion, Shukitt-Hale, and Lieberman, "Caffeine Effects on Marksmanship During High-Stress Military Training with 72 Hour Sleep Deprivation.."

[57] Amy Yang, Abraham A Palmer, and Harriet Wit, "Genetics of Caffeine Consumption and Responses to Caffeine," *Psychopharmacology* 211, no. 3 (June 9, 2010): 245–57, doi:10.1007/s00213-010-1900-1.

[58] ibid.

[59] Emma Childs, Christa Hohoff, Jürgen Deckert, Ke Xu, Judith Badner, and Harriet de Wit, "Association Between ADORA2A and DRD2 Polymorphisms and Caffeine-Induced Anxiety," *Neuropsychopharmacology* 33, no. 12 (February 27, 2008): 2791–2800, doi:10.1038/npp.2008.17.

[60] ibid.

	infarction among (met/met) homozygotes COMT(met/met) do not benefit from amphetamine use	Han: 71-74% Japanese: 71%	fatigue related cognitive decline. Eastern populations may not benefit as much from military-wide amphetamine support for sleep deprivation compared to Western populations.

Command styles & patterns of sleep deprivation in militaries

Military cultures and command styles might influence the effects of sleep deprivation on military performance, simply due to differences in how commanders manage sleep (their own and that of subordinates) and operational cycles. In the US military, and despite evidence that fatigue impairs decision-making, commanders report feeling as though they need to stay awake during ongoing missions. They report a sense of individual responsibility to be available to those in the field should their expertise or support be required. If Eastern cultures place less importance on the role of the individual, would [redacted] commanders be less likely to feel obligated to stay awake during ongoing operations? If so, it could mean that [redacted] – all else being equal –may also better preserve their cognitive functions over the course of extended operations. While an interesting question, there is little in the literature that addresses the issue.

If there are differences in how militaries manage and prioritize sleep, predispositional vulnerability to the effects of fatigue would be less important after the first few days of an operation. After only three days of severe sleep restriction even those who are most resistant to sleep deprivation show severe cognitive impairment, meaning after that time performance differences are more likely to be the result of how each respective military incorporates and *enforces* sleep policies. Because perceived self-reported levels of fatigue often do not reflect actual sleep-related performance decrements, if one military regulates sleep for operators during high OPTEMPO, multi-day missions it is likely they will suffer fewer decrements in overall efficiency than one that does not.

Boredom, Repetition, Vigilance

Many mission critical tasks and positions are boring, repetitive, or involve sustaining attention over long hours. The cognitive load of these jobs may differ tremendously. Whether performing a low-load task such as watching for low-probability, but high consequence threats from a guard post, to the high-load tasks of signals intelligence analyst who listens to noisy recordings of conversations in foreign languages for hours on end, they all require a great deal of vigilance and persistence.

Catecholamines, and in particular dopamine, are predominantly responsible for regulating volitional attentional control, but the same genetic factors that are advantageous in the short term are often disadvantageous over extended periods of time or during understimulating tasks. This is because the dynamics of these systems are often non-linear. For instance, the high-dopamine (DA) versions of COMT(met) and DAT1(9R) correlate with better cognitive performance in short cognitive tasks, but *performance drops faster as tasks last longer than in those with low-DA versions of each gene*. Specifically, those with high-DA versions were slower after 20 minutes than those with high-DA versions of each allele.[61]

Vigilance-based tasks in military settings most often last a good deal longer than 20 minutes, and are more complicated than the simple button-press task used in laboratory settings, which means the effects observed in the lab could be smaller than those we would expect to see in the field. [redacted], for instance, have to triage, translate and interpret hours of meaningless conversation to discover usable and actionable information. They work from recordings that are often incomplete or degraded by noise or other interference, have to distinguish between speakers, determine relationships, and interpret meaning from coded language (i.e., terrorists are unlikely to use the term 'bomb' over the phone). Because there is a constant stream of incoming intelligence, the analysts always have more material to process than they have time to complete the work. Moreover, eight hours of processing on a normal day may extend to twelve-hour days or longer during a crisis. Sustaining attention may be even more difficult for low cognitive load work – such as standing guard – that also induces drowsiness. In all cases, lapses in sustained attention impair perception, which as the first stage in cognitive information processing would have deleterious cascading effects on the other components of building situational awareness. Losing a conversation thread can lead to incorrect assessment of the recording, and unengaged surveillance can miss subtle indicators of an impending attack, for instance. In these instances, the a small amount of residual dopamine left over in those with inefficient clearing mechanisms (COMT(met) and DAT1(9R)) is thought to

[61] Julian Lim et al., "Dopaminergic Polymorphisms Associated with Time-on-Task Declines and Fatigue in the Psychomotor Vigilance Test," ed. Thomas Boraud, *PLoS ONE* 7, no. 3 (March 16, 2012): e33767, doi:10.1371/journal.pone.0033767.s001.

support engaged attention despite such monotonous, tedious work. Supporting this mechanistic theory are studies linking COMT(met) and DAT1(9R) vigilance-related performance.

There is a higher frequency of COMT(met) in Eastern compared to European populations, but DAT1(9R) is lower in frequency among Han and Japanese populations compared to Western groups. When taken together this implies that any advantage Eastern populations may have in sustained operations from higher DAT1(9R) frequencies would balance against any advantages Europeans may find with lower COMT(met) frequencies among the ranks. However, COMT and DAT1 regulate dopamine in different areas of the brain, which correspond to different brain functions.[62] DAT1 regulates DA in regions responsible for overall wakefulness and arousal, whereas COMT regulates DA mainly in the prefrontal cortex, which is responsible for attention control, complex problem solving, executive functions and decision-making. This suggests that a higher percentage of the Eastern population may be better able to maintain generalized alertness over an extended period of time than Westerners, which would be useful while standing watch, scanning for roadside bombs, or manning a missile bunker. A higher percentage of Westerners then may be predisposed to sustain executive function and attention, and thus a greater cognitive load over a longer period of time (See Table 5).

The types of military functions, operations and missions differentially affected would likely then diverge between those that are sustained but high in cognitive-load, versus those that are sustained but low in cognitive-load. The above description of a [redacted] would be a high cognitive-load role and mission, as would be the long hours of a [redacted] operator continually monitoring areas of operations to build a common operating picture for coordinating between air and ground forces. Western militaries may have an advantage over Eastern militaries in high cognitive load vigilance tasks.

A low cognitive load functions, on the other hand would involve monitoring systems or areas of operations for low-probability events, such as missile defense radar operators who must remain alert over many long uneventful hours. A sniper's reconnaissance mission is another example; once in position, snipers often sit for as long as eight or ten hours in a single location waiting and watching for events of interest. In these types of low-grade sustained missions, Eastern militaries may have an advantage over Western militaries in sustaining vigilance since there is a higher frequency of the low-DA version of DAT1 in Eastern populations.

[62] These two systems work in tandem to regulate tonic (DAT1) and phasic (COMT) dopamine levels in the brain. Over extended time periods, lower tonic DA leads to more effective signaling from phasic DA release. See Lim et al 2012 for discussion.

TABLE 5: Genetic variants linked to vigilance and sustained attention control

High dopamine SNP variant & population frequencies	**DAT1 (9R)** Europeans (24-37%) Middle Easterners (45-55%) Han (16%) Japanese (1%) Russian (12%)	**COMT(met)** European (52%) Han (71-74%) Japanese (71%)
Related cognitive functions	Generalized arousal, wakefulness (striatal DA regulation)	Executive function, Attention, Problem solving (prefrontal DA regulation)
Short duration tasks	Better high-load working memory Better motor inhibition	Higher working memory, fewer errors on executive tasks
Long duration tasks >20 minutes	Response speeds degrade faster	Response speed degrades faster
Theoretical effects for extended missions.	May lead to generalized fatigue during sustained tasks	May undermine sustained high-cognitive function
Military units/functions most likely affected	[redacted]	[redacted]

Cognitive load may differ between comparable units and levels of command between militaries depending on the duties and roles that are expected of those units and commanders. For instance, a small unit commander in the US military is expected to adapt operations as missions unfold; the same is not true of a small unit commander in the [redacted] who is encouraged to execute a pre-determined, pre-approved plan. While both functions would impose a good deal of cognitive load in the heat of combat, adapting a plan and executing a mission would likely take a greater amount of complex problem solving and decision-making compared to executing a pre-determined, mentally rehearsed mission. In this case, the potential advantage Western militaries might have from a larger percentage of low-DA COMT carriers in command of small units[63] may offset any disadvantage in terms of cognitive fatigue that may come from sustaining higher-cognitive load tasks.

All of this assumes that COMT and DAT1 variants are present in the same frequencies in these vigilance-demanding operational groups as they are in the greater regional population. These operational roles, however, have high turnover and burnout rates which suggests operators may self-select according to their ability to sustain and tolerate this kind of work. Thus, we may find inflated frequencies of low-active COMT and DAT1 carriers in SIGINT populations simply because they tolerate the work better, and thus any comparative advantage based on national population-level differences would be overwhelmed by self-selection dynamics. If [redacted] operators, on the other hand, feel the need to fulfill their duty in spite of personal preference, the frequency of DAT1(9R) and COMT(met) in their analysts may more closely resemble that of the greater [redacted] population.[64]

[63] Assuming the population of commanders for each nation has similar distribution to the greater respective national populations.
[64] Unless, of course, the [redacted] uses genetic markers for selection purposes.

Acute Stress

The most obvious performance disruptor in military settings is the acute stress that comes from direct threats to life in combat operations or other high stakes scenarios. Extensive research of the effects of acute stress on cognition in both humans and animals has revealed much about stress-induced changes in neural signaling and behavior, even if some detailed cognitive mechanisms are still up for debate. Acute stress stimulates the hypothalamic pituitary adrenal axis (HPA Axis), which not only stimulates the release of adrenaline in the body to facilitate the

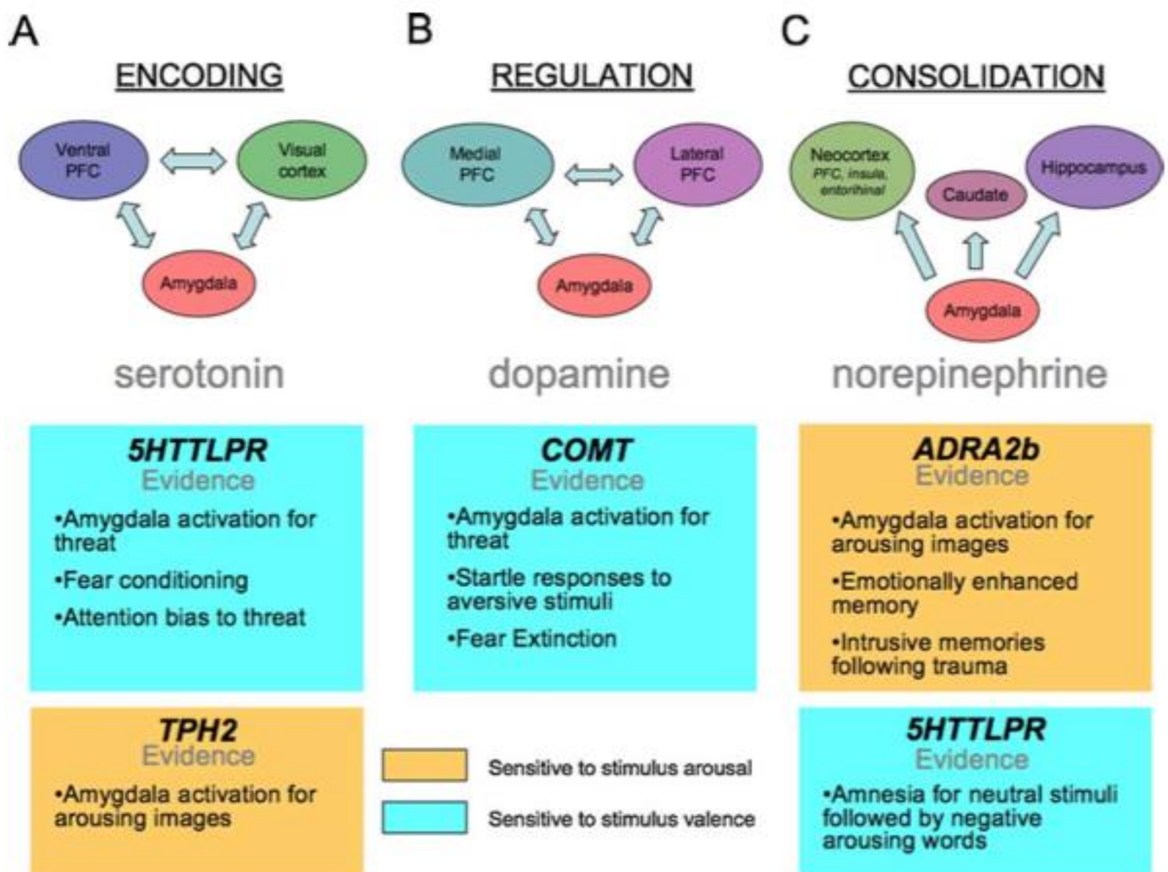

FIGURE 11: The relationship between genetic variants, neurotransmitters and cognitive processes. A. The serotonin transporter gene and TPH2 influence serotonin levels, which in turn may influence how one perceives threat (encoding). B. COMT [and DAT1] influences dopamine regulation and executive control of the threat-reactive amygdala. C. ADRA2b and the serotonin transporter both influence norepinephrine release via amygdala activation and influence threat reactivity and memory formation. (From Todd, 2011 et.al.)

physical "fight or flight" response,[65] but also stimulates dopamine (DA) and norepinephrine (NE, or noradrenaline) in the brain, which has very specific effects on attention, threat reactivity and behavior and implications for combat performance. Serotonin levels are also involved and shape both whether and how stimuli are interpreted as threatening. Stress-related dysfunction in combat has been defined as Operational Demand-related Cognitive Decline (ODRCD),[66] which is the "decrement in cognitive performance or decision-making resulting from the manifold pressures or acute stressors characteristic of dangerous or extreme environments."[67] How different cultures view and react to stressful contexts and potential differences in stress-related regulatory mechanisms could influence Eastern and Western militaries in divergent ways.

Neurocognitive effects of stress

Dopamine and norepinephrine are responsible for regulating volitional attention. Moderate stress and amounts of these neurotransmitters promote executive functions directed by the frontal lobe, including attentional focus and memory recall. Severe stress causes a flood of DA and NE, which over-stimulate frontal regions of the brain and undermine executive functions. When executive function is compromised, there are a number of problematic cognitive effects including: narrowed attention and increased distractibility; overreliance on automatic habitual reactions; and, increased threat reactivity and reduced emotional control.

Narrowed focus and increased distractibility. Whether from fear, anxiety or even just high workload, stress narrows the attentional spotlight[68,69] which limits the amount of information one can receive and process. Initially this can improve performance by blocking out irrelevant peripheral information. As arousal moves beyond an optimum state however, performers begin to miss critical information and focus becomes difficult. In other words, during severe stress, attention is both narrowed and poorly directed even in spite of increased efforts to focus. One study showed that increased effort to focus on task-relevant information was not enough to overcome distraction from an unpredictable threat of shock.[70] Evidence in soldiers undergoing highly-stressful SERE (survive, evade, resist and escape) training reveal similar results; when

[65] The most common response in animals and humans is actually to neither flight nor fly, but to freeze.
[66] Which is related to, but broader than Combat Stress-Induced Cognitive Decline (Lieberman et al 2005)
[67] JEFFREY A McNeil and C Morgan, "Cognition and Decision Making in Extreme Environments," *Military Neuropsychology*, 2010, 361–82.
[68] J A Easterbrook, "The Effect of Emotion on Cue Utilization and the Organization of Behavior.," *Psychological Review* 66, no. 3 (May 1959): 183–201.
[69] Michael W Eysenck and Manuel G Calvo, "Anxiety and Performance: the Processing Efficiency Theory," *Cognition & Emotion* 6, no. 6 (1992): 409–34.
[70] Bartlett AH Russell and Bradley D Hatfield, "Controlling Attention in the Face of Threat: a Method for Quantifying Endogenous Attentional Control," 2013, 591–98.

asked to copy a complex line drawing (The Rey Osterieth Complex Figure task, or ROCF) some soldiers took a narrow inefficient piecemeal approach (moving from one small detail to the next) rather than a more adaptive holistic approach.[71]

Such effects would be most deleterious for military tasks and units that require multitasking or careful concentration on mission critical information in the face of generalized threat of life, such as in fighter pilots, elite ground forces, and explosive ordinance disposal (EOD) units. Narrowed attention would limit, for instance, the number of instruments a pilot could attend simultaneously. In a recent study of Naval aviation students, as cognitive load increased in a flight simulation, the students' gaze behavior changed from a methodical pattern for checking each instrument to an erratic pattern that included more task-irrelevant gaze shifts.[72] In this way, less information is processed (narrower attention) and a higher percentage of that information is irrelevant (increased distractibility), which compromises quality and depth of one's situational awareness. Not surprisingly, [redacted] is dedicated to what is known as 'stress inoculation' by inducing stressful contexts so that operators can learn to maintain cognitive presence - preventing attentional narrowing and distraction - to support decision-making under threatening conditions.

Learning and memory. As noted earlier, moderate levels of stress can both promote memory formation and memory recall. Classical neuroscience experiment in slugs, mice and humans all demonstrate serotonin's role in forming aversive associations between unpleasant stimuli and environments. More severe and especially uncontrollable stress can degrade memory.[73] The above-mentioned ROCF task also has a memory component. In addition to the altered attentional patterns, soldiers in SERE training also showed short-term memory deficits during stress.[74]

Such memory-related deficits are thought to be related to dissociation. Dissociation is a disconnection between of one's perceptions of the environment and his sense of self within that environment. Loss of holistic environmental engagement (such as the SERE students exhibited in the drawing task) is one example. Other symptoms include the feeling that events

[71] McNeil and Morgan, "Cognition and Decision Making in Extreme Environments."
[72] Bradley D. Hatfield, unpublished data, 2014.
[73] S T Morgan, J C Hansen, and S A Hillyard, "Selective Attention to Stimulus Location Modulates the Steady-State Visual Evoked Potential.," *Proceedings of the National Academy of Sciences of the United States of America* 93, no. 10 (May 14, 1996): 4770–74.
[74] C A Morgan et al., "Relation Between Cardiac Vagal Tone and Performance in Male Military Personnel Exposed to High Stress: Three Prospective Studies," *Psychophysiology* 44, no. 1 (January 2007), doi:10.1111/j.1469-8986.2006.00475.x.

are moving in slow-motion, colors may become either unusually bright or dull, sounds seem unusually far away, and even ‘out of body’ experiences. It is thought that this sort of dissociation is a protective response to prevent the formation of memories of severe trauma, by decoupling areas of the brain responsible for executive function (prefrontal) and memory formation (hippocampus). Even if protective, dissociation can have deadly operational effects if a solider disconnects from reality in a life-threatening situation. As discussed below, some factors may affect individual vulnerability to this sort of acute-stress related dysfunction.

***Threat reactivity and emotional regulation**.* Unfamiliar stimuli activate the threat-center of the brain (the amygdala). Under normal circumstances frontal executive regions exert top-down control over the limbic system and amygdala sound thereby regulating emotional responses and over-reaction. This is the type of process that occurs when for instance, one hears a creak in the house but takes a moment to consider all of the potential non-threatening sources rather than jumping to the assumption an intruder made the noise. Because stress undermines the frontal executive regions, however, it increases generalized reactivity to unfamiliar stimuli whether or not it is threat related. In combat operations this could mean operators are quicker to assume hostile posture and use kinetic force against a car approaching a checkpoint for instance. Operationally this could cause unnecessary escalation of kinetic force, sometimes with strategic consequences. For the operators themselves, if the stress reaction is not regulated, persistent indiscriminant scanning for uncontrollable threat can lead to stress-related injury such as chronic stress-related hormonal dysregulation or even vulnerability to post traumatic stress disorder.

Automaticity and Negative Regression. Practice and training are effective because they turn explicit, conscious task execution into an automatic habitual process, thereby freeing cognitive resources to attend to other demands. This sort of habit building can be both advantageous and problematic under stressful conditions.

Habitual, or automatic skill sets are less vulnerable to the effects of stress because automatic processes are not governed by the frontal executive regions that are most sensitive to stress hormones. An experienced driver, for instance, does not need to think before pressing the breaks when a deer jumps into the road. A novice driver, however, may have to consciously remind himself which pedal – the left or right – is the break before taking action. That kind of executive decision-making process is highly dependent on frontal regions, which is also the area that is first to be compromised during stressful events. When he does decide, his physical reaction will also be kinematically awkward, inefficient, and often exhibit perseverative re-direction (i.e., 'waffling'), increased 'jerk,'[75] and inappropriate force. Similarly, acute stress has how to impair shooting performance efficiency.[76] Practice, training and habit-formation build skill 'automaticity' where little to no executive involvement is necessary to execute habitual motor 'programs'. The learning processes involves moving the locus of skill control out of executive frontal regions into motor and premotor processing areas that are less sensitive to stress and stress hormones. In this way, automaticity inoculates one to stress by insulating the motor program.

Automaticity can also present challenges when operators adapt to new platforms. When pilots, for instance, fly a new platform under stressful conditions they can inadvertently revert to automatic habits they built on a previous platform. [redacted] Stress reduces conscious executive control, and thus increases the likelihood a pilot will revert to a habitual motor response rather than a newly learned one. In some cases it means reaching for a switch in the wrong place, or applying the wrong amount of pressure to the stick or rudder control.

Such imprecise stick control and subsequent overcorrection causes what is known as 'pilot induced oscillation' (PIO). PIO can cause a pilot to lose complete control of the aircraft, [redacted] The risk of PIO is greatest in novice pilots, but even [redacted] are at risk when unfamiliar with a platform. The best way to avoid stress-induced negative regression is to train at length with the new system, and the same system that is to be used in actual combat operations.

Military-cultural approaches to training on combat platforms will have the most impact on shaping neurocognitive differences in terms of resistance to the effects of combat related stress. As will be discussed below in the section on training, the US military's emphasis on live training exercises may give the US a cognitive advantage under stress compared to militaries. The [redacted] also uses live training exercises, much of which is stressful, but over the past 20 years has increased simulation-based training as a cost-cutting strategy. The [redacted] also discourages training with certain expensive weapons system to prevent wear and tear and preserve the longevity of the system. An increased reliance on simulation without ample time training with the real system may lead to some level of unfamiliarity with the system during combat. This means [redacted] operators will have to engage executive high-load cognitive functions during a time

[75] Jerk is a measure of change in acceleration, quantified as the third derivative of speed and is indicative of inexperienced and inefficient motor control.

[76] Tharion, Shukitt-Hale, and Lieberman, "Caffeine Effects on Marksmanship During High-Stress Military Training with 72 Hour Sleep Deprivation.."

when those functions are limited by stress-induced neurotransmitter signaling. Additional cognitive effort may be sustainable over short time periods, but would impose greater cognitive fatigue as combat went on. Similarly, if they train predominantly on simulators but not on the real weapon system, negative regression to simulator-specific controls would be more likely than in a military that trains as it fights. [redacted] is a notable exception in this regard because it has made a conscious effort to increase their fighter pilots' flight hours to meet US averages (200 flight hours). It is unclear how much, if at all, this policy extends to other weapons systems.

Genes related to acute stress response	DAT1	COMT	ADRA2B	5-HTTPLR	NPY
Population frequencies	**DAT1 (10R)** European (63-78%) Middle Eastern (45-55%) Han (84%) Japanese (99%) Russian (88%)	**COMT(val)** European (48%) Han (26-29%) Japanese (29%)	**Deletion** European (28-33%) Han (46-48%) Japanese (31-35%)	**5-HTTPLR(s)** European (45%) Eastern (Han, Japanese & Korean) (75%)	**NPY(C)** European (4-6%) Eastern (Han, Japanese & Korean) (~0%)
Laboratory findings	Generalized arousal, wakefulness (striatal DA regulation)	Clears stress-induced norepinephrine from prefrontal regions more efficiently	Increased response to potential threat More likely to form emotional memories	Less efficient clearing of serotonin, heightened reactivity to potential threat	Increased NPY released under stress decreases norepinephrine release
Theoretical effects for extended missions.	*May lead to generalized fatigue during sustained tasks*	*May enable attention and executive functions under stress*	*Possible increased distractibility in stressful contexts and increased traumatic memory formation*	*Increased risk of emotional disorders and sensitivity to trauma – but only in independent cultures*	*Resistance to stress & combat stress-related injury*

Military units/functions potentially affected	***Possible Eastern advantage** in cognitively demanding tasks under stress* *Both DAT1(10R) and COMT(val) could support performance in high stress roles that require large amounts of skill, focus and executive thinking such as;* • *Helicopter pilots* • *RECON Snipers* • *Explosive Ordinance Disposal (EOD) units* • *Direct action, assault and raids*	***Possible Western advantage** i in cognitively demanding tasks under stress* •	***Possible Western advantage** in the ability to maintain focus under high-stress situations and in reduced risk of disruptive traumatic memories* ***Possible Eastern advantage** in threat detection*	***Possible Eastern advantage** due to a strong interaction with collectivism.* [77] • *Combat operations including:* • *Crisis management*	***Possible Western advantage** over the course of multiple deployments. Fewer losses of elite unit high-value operators to psychological injury.*
Real world evidence?	*Both COMT & DAT1 show a relationship with cognitive performance under stress, but it is not clear if any potential Eastern advantage in DAT1(10R) frequency is offset by a potential Western advantage due to higher COMT(val) frequencies. There is no also no behavioral evidence of one population exhibiting greater average cognitive presence under stress than the other.*		*Those exposed to trauma have more intrusive emotional memories of the events.*	*Fewer mood and anxiety-related disorders in collectivist nations.*	[redacted] *selectees have a greater NPY response to stress compared to those cut from selection*

While differences in training will have the most influence on whether units are sufficiently stress-inoculated, predisposition to stress sensitivity may also affect performance under pressure. In the aforementioned ROCF drawing task, only some soldiers exhibited degraded performance. In another example, both irrelevant and relevant peripheral information

[77] Though the short variant is higher in Eastern populations, it is not a risk factor in collectivist societies.

distracted anxious drivers to a greater degree than non-anxious drivers.[78], Vulnerability to stress-related cognitive impairment and ODRCD could be due a predisposition to anxiety, to learned maladaptive coping strategies, or both (the former may be causally linked to the latter). In theory, stress induced in training should weed out those who are susceptible to stress-induced dysfunction yet members of even select groups such [redacted] report symptoms of dissociation and exhibit ODRCD. Moreover, in today's irregular battlefield, non-combat units are often exposed to the kind of stress previously only experienced by the front lines. Improvised explosive devices (IEDs), for instance, are as much a threat to supply and logistic convoys as they are to combat patrols, and impose particularly harmful type of uncontrollable and unpredictable stress. For these reasons, it is worth considering how differences in stress-sensitivity and susceptibility to stress-related cognitive impairment compare between Eastern and Western populations. There are a number of genetic variants that might play a role (see Figure 15, above) in individual resilience and sensitivity to stress and specific stress-related cognitive effects because of how they influence concentrations of dopamine, serotonin and norepinephrine.[79]

Due to the relationship between stress, norepinephrine and dopamine release in response to stress, and the effect these neurotransmitters have on attentional focus and narrowing, factors that affect the regulation of these neurotransmitters could influence cognitive resilience to stress. Thus, for the same reasons the low-active versions of COMT and DAT1 might be advantageous in repetitive sustained tasks, they can disadvantageous in stressful contexts.[80] COMT(met/val) has been called the "worrier/warrior" gene;[81] the low-active COMT(met) allele does not clear dopamine as efficiently as the high active COMT(val) allele. Under normal conditions the low active COMT(met) carrier have a little extra dopamine to help them focus during monotonous tasks. Under stress however, when the frontal cortex is flooded with large amounts of dopamine, the COMT(met) carriers are unable to clear DA quickly enough to prevent overstimulation and may be faster to show attentional narrowing, impaired executive functions and increased threat reactivity. The COMT(val) carriers on the other hand, clear DA very quickly and though that can make it more difficult to focus during monotonous tasks, it can also prevent frontal overstimulation from surges in stress-induced DA. Hence COMT(val) is

[78] N P Murray and C M Janelle, "Event-Related Potential Evidence for the Processing Efficiency Theory," *Journal of Sports Sciences* 25, no. 2 (January 15, 2007): 161–71, doi:10.1080/02640410600598505.
[79] R M Todd et al., "Genes for Emotion-Enhanced Remembering Are Linked to Enhanced Perceiving," *Psychological Science* 24, no. 11 (November 8, 2013): 2244–53, doi:10.1177/0956797613492423.
[80] Nina Alexander et al., "Genetic Variants Within the Dopaminergic System Interact to Modulate Endocrine Stress Reactivity and Recovery.," *Behavioural Brain Research* 216, no. 1 (January 1, 2011): 53–58, doi:10.1016/j.bbr.2010.07.003.
[81] Dan J Stein et al., "Warriors Versus Worriers: the Role of COMT Gene Variants," *CNS Spectrums* 11, no. 10 (2006): 745.

known as the 'warrior' variant, and COMT(met) as the 'worrier' variant. Similarly, DAT1 regulates dopamine through more central areas of the brain related to generalized arousal; the longer (10 repeat) version clears dopamine more quickly and like COMT(val) has been linked to better stress-related performance. If these variants support executive functions in general, they should support emotional regulation under stressful events as well. Interestingly, however, the combination of COMT(met) and DAT1(10R) is associated with particularly high cortisol responses to stress compared to all other groups.[82] This is a curious epistatic interaction because we would predict such stress sensitivity from COMT(met) but not from DAT1(10R) which shows us how little we can infer from the frequency of single genetic variants.

***Sensitivity to psychological stress-induced injury*.** While COMT and DAT1 may affect how well one thinks and regulates their emotional response to stress, other factors may affect how sensitive one is to threat in the first place, and thus how vulnerable he or she may be to stress-related psychological injuries such as posttraumatic stress disorder (PTSD). Two factors have been connected to emotional sensitivity and emotional memory formation. The short version of the serotonin transporter variant (5-HTTLPR9(s)) is associated with reduced top-down control of emotional control, heighted threat reactivity and is a risk factor for depression in those exposed to trauma at an early age.[83] Similarly the ADRA2B deletion and TPH2(T) variants are both associated with stronger emotional memory formation, greater response to threats and indiscriminant hyper arousal to potential threat (threat scanning behavior), and harm avoidance behavior. These hyper-reactive tendencies would not only affect a warfighter over multiple deployments but would also have the second order consequence of decreasing re-enlistment rates and eroding operational experience among the ranks and in command.

From the laboratory research, and because Eastern populations have higher frequencies of all three risk related variants (5-HTTPLR(s), the ADRA2B deletion and TPH2(T)) we would guess Eastern militaries would be more vulnerable to stress-related injury. The evidence however, is exactly the opposite. Eastern populations have a far lower incidence of anxiety, mood and depressive disorders compared to Western groups, which is likely due to differences in familial support systems in collectivistic societies compared to individualistic ones.[84] This means that regardless of genetic variants, Western militaries will be at greater risk of stress-induced psychological injury due to a relative lack of group support systems in individualistic societies.

[82] Nina Alexander et al., "Behavioural Brain Research," *Behavioural Brain Research* 216, no. 1 (January 1, 2011): 53–58, doi:10.1016/j.bbr.2010.07.003.
[83] Todd et al., "Genes for Emotion-Enhanced Remembering Are Linked to Enhanced Perceiving."
[84] Chiao and Blizinsky, "Culture-Gene Coevolution of Individualism-Collectivism and the Serotonin Transporter Gene."

Adaptive responses to threat: Neuropeptide Y. Neuropeptide Y is released in response to stress to and inhibits the release of norepinephrine (noradrenaline) and seems to be related to resilient responses to stress. [redacted] soldiers, for instance, seem to mount a larger NPY response, which corresponded to better training-related task performance, during stress compared to non-SF groups.[85] Those with higher NPY levels also showed reduced symptoms of dissociation, which are experiences of altered cognitive processing such as the perception that things are moving in slow-motion or that sounds seem distant. Likewise, those with Post Traumatic Stress Disorder exhibit reduced levels of NPY and mount blunted responses to pharmacologically-induced anxiety.[86]

Though rather uncommon compared to other polymorphisms discussed here, there is a polymorphism associated with the gene that affects the packaging and release of NPY. A cytosine (C) substitution (rs16139) seems to correspond to greater NPY release, and therefore better responses to stress.[87,88] Interestingly, the polymorphism is rather rare, occurring in only 5% of Northern European[89] populations and is virtually absent in Chinese and Japanese populations. If dispersed evenly throughout the greater military this sort of polymorphism is unlikely to have much impact on overall stress resilience of one military compared to another. However, it has been hypothesized that the selection procedures for elite may include a population with a higher-than-average incidence of this polymorphism. To date and to our knowledge this sort of genetic analysis has not been done in [redacted] have exhibited excellent performance on assault exercises associated with elite units in international special operator, sniper and police competitions [90] these exercises do not replicate the level of life-threatening stress experienced in actual combat operations.

If selection does concentrate the NPY(C) polymorphisms in elite units, it suggests that such unit in the US may be more resilient in the face of stress than those from the [redacted] An additional benefit to this sort of resilience would be increased retention of SF and SOF operators over a

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[85] Charles A Morgan et al., "Neuropeptide-Y, Cortisol, and Subjective Distress in Humans Exposed to Acute Stress: Replication and Extension of Previous Report.," *Bps* 52, no. 2 (July 15, 2002): 136–42.

[86] A M Rasmusson et al., "Low Baseline and Yohimbine-Stimulated Plasma Neuropeptide Y (NPY) Levels in Combat-Related PTSD.," *Bps* 47, no. 6 (March 15, 2000): 526–39.

[87] Morgan et al., "Neuropeptide-Y, Cortisol, and Subjective Distress in Humans Exposed to Acute Stress: Replication and Extension of Previous Report.."

[88] Rasmusson et al., "Low Baseline and Yohimbine-Stimulated Plasma Neuropeptide Y (NPY) Levels in Combat-Related PTSD.."

[89] Interestingly, the NPY(C) variant is most frequent in Nordic populations.

[90] [redacted]

career (i.e., fewer lost to psychological injury) and thus, a better response to ‘stress inoculation’ based training and a higher level of combat experience among existing units.

In terms of stress-inoculation and, the most significant advantage the US military has in terms of maintaining cognitive capabilities under stressful contexts may be that enlisted and commanders have combat experience from more than a decade of ongoing operations in Afghanistan and Iraq. Coincidentally, this may also be the US military’s biggest weakness when it comes to suffering the effects of chronic stress, which we will discuss in the next section.

CHRONIC STRESS/ ONGOING OPERATIONS

There are different physiological, psychological and cognitive effects from stress that extends beyond a few days, and this sort of chronic stress is a common feature of military deployments. For instance, extended deployments, especially if units are unaware of whether their tours will be extended as was common among Stryker brigades stationed in both Iraq and Afghanistan over the last decade. Support units such as those transporting supplies and other materiel in insurgent-populated regions suffered the daily stress of watching for, and worrying about roadside explosives or other improvised explosive device (IED). Chronic stress is thus a function of factors that affect reactions and resistance to acute stress, but there are distinct cognitive consequences when stress lasts beyond a few days or weeks and extends over months such as a reduced ability to mount an effective response to immediate threat due to dysregulated glucocorticoid function, and impaired memory systems. [91]

Factors that may shape how chronic stress manifests in Eastern and Western populations are both culturally influenced in terms of threat perception, and may also be related to underlying biological sensitivities. The consequences for a military are two-fold; the first order effects chronic stress has on learning and memory functions and the second order effects it as on operator burnout, reduced reenlistment and loss of combat experience, and the added tragedy and cost of psychologically-injured veterans.

A sense of control. The stress that comes from daily patrols and convoys along IED-studded roadways is an example of the one of the most cumulatively damaging types of stress: unpredictable and uncontrollable threat. Part of the reason stress inoculation works is that it teaches people to deal with stress by focusing externally on ways they can control and improve the situation; if a soldier keeps his wits about him during a fire-fight for instance, he will have a better chance of eliminating the source of threat. The sense of control is vital in this regard. In both animal studies and in human clinical research, in the absence of a sense of such control animals and people will develop *learned helplessness*[92] or a sense that they can do nothing to improve their situation.

The cultural dichotomy between Eastern and Western philosophies regarding how much control one has over the world may affect relative vulnerabilities to certain kinds of operational-related stress. Animal studies in which rats are subject to unpredictable and uncontrollable foot shock suggest that all mammals are subject to the effects of unambiguous

[91] Bruce S McEwen, "Protection and Damage From Acute and Chronic Stress: Allostasis and Allostatic Overload and Relevance to the Pathophysiology of Psychiatric Disorders," *Annals of the New York Academy of Sciences* 1032, no. 1 (December 2004): 1–7, doi:10.1196/annals.1314.001.

[92] This is one reason prayer is thought to be an effective coping mechanism since it provides a perception of influence.

threats (i.e., threats to life, pain, etc.). However, perceptions of other types of stressors differ. Uncontrollable stress could be more disruptive for a Westernized individualist who believes that he has control over his future and should strive to achieve a desired outcome. A commander with a greater sense of agency would also feel greater obligation to stay up long hours for instance, which is a common source of chronic stress. The Eastern mentality may then be protective in this regard; less sense that one *can* do something may reduce the sense that one *should* do something.

The same may not be the case for social situations. Instead, because of the increased importance placed on work and family relationships, collectivists may be more vulnerable to the chronic stress from social disapproval or shame. Western individualists may be more resistant to such social stressors, as is illustrated by a number of ill-behaving celebrity socialites in Western media. Within military contexts then social pressures within hierarchical ranking may be more stressful for a [redacted] officer, whereas the consequences of decisions-made (and potential lives lost) might impose more stress for a US commander. The [redacted] command structure disperses decision-making responsibility within the network of military and political commander and alleviates such pressures with group decision-making practices. In US, on the other hand, commanders are solely responsible for their command decisions, which depending on the level of command can either affect the lives of dear friends within their unit or the lives of larger numbers of soldiers across multiple units. Ironically, group decision making like that done in the [redacted] may not be less stressful for the independent-minded. Commanders comment that the idea of having a political officer overseeing all of their decision-making would be "maddening".[93]

There is very little evidence available to corroborate these ideas. The best we can do is to consider the interaction of collectivism and the lower incidence of anxiety related disorders. If such illnesses are less frequent in interdependent societies it is likely that chronic stress-related impairments would also be less likely.

Chronic stress and memory. Stress enhances memory formation to facilitate learning how to deal with or avoid that threat in the future. If a stress is ongoing, unrelenting and uncontrolled, however there is little to be learned from the memory. The memory may instead impose emotional pain and additional stress. In such cases preventing memory formation may be a way to prevent further stress-related injury. This may be why in laboratory settings chronic stress shows profound effects on memory systems. In particular, chronic stress seems to negatively affect the rate at which neural connections are made in the brain and causes atrophy in the rodent memory center (hippocampus). Just as with acute stress, any factor that affects

[93] Participant, NeuroCognitive Divide Workshop. Scitor Corporation, Rosslyn Virginia, 3 June 2014.

emotional memory formation should also affect emotional reactive mechanisms over an extended period of time.

There are differences in both learned and acquired sensitivity to chronic stress. An adaptive response to acute stress involves a sharp HPA response followed by a return to homeostasis. In a healthy stress response the adrenals (the last stage in the HPA axis) release the stress-protective hormone cortisol, which provides a slightly delayed feedback loop to inhibit continued hypothalamic and pituitary neurotransmitter release and reinstate homeostasis. If stress is persistent over an extended period, cells become insensitive to cortisol and the cortisol response itself becomes irregular.[94] Those that appear to be the most resistant to the effects of chronic stress are those who are able to down-regulate their stress responses to threat quickly after an acute threat has subsided. Those who ruminate on a past or potential threat, on the other hand, continue to drive the stress response and related hormones. Since anxiety is a reaction to potential threat, high-anxious individuals (like those discussed in the previous section) are more likely to ruminate and may then also be susceptible to chronic-stress. Cognitive reappraisal and mindfulness techniques in which one focuses externally on things in the environment he can control and minimizes worry over things outside his control are can be effective behavioral therapies for addressing one's response to stress even if not one's initial reaction to chronic stressors.

There may be at least two acquired factors that affect vulnerability to chronic stress. Those with the Met66 version of the BDNF(val66met) allele may exhibit reduced working memory, declarative memory[95] and susceptibility to acute stress related disorders like PTSD due to lower levels of memory-forming BDNF.[96] Very interestingly, however, the same risk factor for PTSD (BDNF(Met66)) was protective against chronic social defeat stress, possibly because it impaired consolidation of trauma-inducing memory formation.[97] The BDNF(met) variant is more frequent in Eastern (38-49%) compared to Western (19%) populations suggesting that a greater percentage of Eastern military ranks may be resilient to chronic stressors such as those observed in extended deployments. Historically, the [redacted] has prided itself on being made up of 'hearty peasants' that can sleep outside without decrement. Whether the two

[94] Cortisol will naturally fluctuate throughout the day. A healthy adult will have high waking cortisol and low evening cortisol. A hallmark of chronic stress and adrenal fatigue is a 'flattened' diurnal corticol cycle and a reduction in the ratio of waking to evening cortisol levels.

[95] J Chen, X Li, and M McGue, "Interacting Effect of BDNF Val66Met Polymorphism and Stressful Life Events on Adolescent Depression," *Genes, Brain and Behavior* 11, no. 8 (2012): 958–65, doi:10.1111/i.l601-183X.2012,0C843,x.

[96] L Zhang et al., "PTSD Risk Is Associated with BDNF Val66Met and BDNF Overexpression" 19, no. 1 (January 15, 2013): 8–10, doi:10.1038/mp.2012.180.

[97] Vaishnav Krishnan et al., "Molecular Adaptations Underlying Susceptibility and Resistance to Social Defeat in Brain Reward Regions," *Cell* 131, no. 2 (October 2007): 391–404, doi:10.1016/j.cell.2007.09.018.

factors are related is pure speculation, but the connection between reduced memory and resistance to chronic stress implies that there is a memory-component to the accumulation of stress over time. Just as the perception of stress is necessary for stress-hormone release, it may be that the memory for ongoing stress may be necessary for persistently elevated hormones associated with chronic dysregulation. Regardless, if this is the case, it suggests that Eastern militaries may have a portion of the population with greater resistance to prolonged deployments of ambiguous length.

The memory-impairing mechanism behind BDNF(Met66) carriers' insensitivity to chronic stress also means, however, that carriers may be less able to learn, adapt and avoid chronic stressors no matter how uncontrollable they may be. This would be in many ways operationally disadvantageous even if individually protective. More useful is a trait that promotes adaptive responses to repeated stress and still allows adaptation like the NPY(C) variant. As discussed in the previous section, NPY(C) carriers seem to show increased resilience even after repeated bouts of stress. Such a response is ideal and would prevent chronic stress-related hormone dysfunction as well as allow the formation memories. The variant is rare in general, but Western populations have a slightly higher frequency meaning a very small portion of Western militaries may be chronic-stress resistant and more likely to find themselves in elite units.

Sensitivity to Chronic Stress	BDNF	NPY
Population frequencies	**BDNF(Met66)** European (19%) Eastern (Han, Japanese & Korean) (38-49%)	**NPY(C)** European (4-6%) Eastern (Han, Japanese & Korean) (~0%)
Laboratory findings	Reduced declarative memory performance but possible increased susceptibility to chronic stress disorders such 3PTSD	Increased NPY released under stress decreases norepinephrine release, reducing cumulative effects of chronic-stress
Theoretical effects for extended missions.	*Greater resilience and recovery to combat stress. Questionable ability to adapt and improve performance over time*	*Greater resilience and recovery to repeated exposure to combat stress. Less chronic stress induced hormonal dysregulation and better field performance*
Military units/functions potentially affected	• *Forward deployed support roles in FOBs subject to repeated mortar attacks* • *In-country supply chain and maintenance roles subject to threats from irregular enemy forces* • [redacted] *juggling operational and family pressures simultaneously*	• *Units involved with local populace like Special Forces* • *High OPTEMPO units with repeated redeployments and unpredictable deployment extensions* • *Units that operate at night like* [redacted]
Real world evidence?	*Conflicting evidence of susceptibility to PTSD*	[redacted] *selectees have a greater NPY response to stress compared to those cut from selection*

***Pre-adolescent trauma and stress resilience*.** Early childhood and adolescent experiences shape stress reactivity and resilience to ongoing stressful situations. For example, neglect leads to attenuated corticosterone responses to stress, higher concentration of stress hormone (glucocorticoid) receptors, and more anxious behavior.[98] This phenomenon has been linked to epigenetic changes (methylation of a sequence that promotes production of gluticocorticoid receptors) in rodents. [redacted] This would not only increase the incidence of stress-related anxiety disorders and injury, such as depression and PTSD, but would also affect how these individuals respond to chronic repeated stress.

"I'm not afraid of nuclear war. There are 2.7 billion people in the world; it doesn't matter if some are killed. China has a population of 600 million; even if half of them are killed, there are still 300 million people left. I'm not afraid of anyone."

Mao Zedong

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[98] Weaver I. C. et a.,l Epigenetic Programming by Maternal Behavior. *Nature Neuroscience.* 7 847-854 (2004).
[99] Blosnich, J.R., Dichter, ME, Cerulli, C., Batten, S.V., Bossarte, R.M. et al. Disparities in Adverse Childhood Experiences Among Individuals With a History of Military Service, JAMA Psychiatry. Published online July 23, 2014. doi:10.1001/jamapsychiatry.2014.724

4. OPERATIONAL SCENARIOS AND DEFENSE FUNCTIONS

Divergent neurocognitive patterns and styles are most likely to affect military and intelligence functions that are particularly dependent on cognitive processes such as perception, fusing and interpreting information, developing strategies, and making decisions. The places in which these functions seem most critical to operational and strategic functions are in the areas of intelligence, surveillance and reconnaissance (ISR) and decision making related to command and control (C2). The present section will discuss the potential implications of divergent Eastern and Western perspectives and proclivities on these functions.

INTELLIGENCE, SURVEILLANCE & RECONNAISSANCE (ISR)

Intelligence, surveillance, and reconnaissance (ISR) encompasses a wide range of functions and capabilities all of which are aimed at developing superior situational awareness for military planners, strategists, and decision makers from various sources of information.

Operationally, the Chief Scientist of the Air Force, Dr. Mica Ensdley, defines Situational Awareness (SA) as a three level process:

- **Level 1:** ***Perception*** of the environment including determining what is salient. This is also the level where most errors in SA occur in pilots. [100]
- **Level 2:** ***Comprehension*** of the situation including correctly interpreting
- **Level 3:** ***Projection*** of how the dynamics of the current situation will shape future outcomes and how actions may influence those outcomes.

This is a simple version of SA is geared towards pilots. ISR analysts have the additional burden of actively pulling information (rather than merely consuming information) and packaging that information – once perceived, comprehended and projected – into intelligence products to communicate that SA to forward units. This involves: prioritizing collection requirements, managing requirements against collection assets, coordinating team products and multisource information, and providing operational support such as validating targets, assisting battle management and coordinate attacks, maintaining awareness for detecting emergent threats.

PERCEPTION

[100] Jones & Endsley 1996

Patterns in attention, short and long term memory all affect perception and how information is integrated. Attention is the limited intake-valve for cognitive information processing that prioritizes between active (focus) and passive (alerting) information intake processes. Neurocognitive differences and cultural preferences for certain information (i.e., context versus object bias, or interpretation of stimuli as neutral or threatening) change this prioritization, which will affect what information is incorporated into both the individual and shared mental model of the operational situation.

Attention mechanisms automatically prioritize certain kinds of information over others depending on 1) inherent saliency, or information that is universally important to humans such as a threatening face, and 2) what we have learned to be salient. Inherently salient information is that which is important for survival such as a threatening human face, food rewards, or pain. We learn that other information is salient usually because it is associated with something inherently salient. Just like Pavlov's dogs, if learn to associate a sound with food, that sound will also likely grab our attention. This extends to socially influenced cues, rewards, and hierarchies – all of which are heavily influenced by culture.

We can then expect information to be prioritized in an ISR context similarly to how it is valued within a culture. As such, context should – according to Nesbitt's dichotomies - garner a higher attentional priority in an Eastern analyst cell than in a Western cell. Though all analysts certainly have the ability to consider contextual information regardless of cultural influence, ISR cells are notorious for having far more requirements and raw intelligence to process than they have time. As a result, analysts rely heavily on heuristics and would have a tendency to revert to habitual culturally-influenced thinking patterns under time-pressure constraints. It seems unlikely that when a Western analyst is scanning imagery intelligence for enemy movements, for instance, that while looking for vehicles, convoys or formations (objects) he would discount the terrain (context). He may, however, be more likely to overlook a contextual detail that may affect group movements than a piece of artillery, for instance.

If culturally bound neurocognitive differences affect what different people perceive from the same information sources, then these differences are likely to affect not only the consumption of raw intelligence, but also what kind of intelligence analysts seek in the first place. Eastern emphasis on the influence of context may mean Eastern analysts spend more time seeking and incorporating contextual information or trying to understand relationships than Western analysis. It may also mean that the [redacted] could misattribute the importance of those items when considering how they affect military decision-making in the US.

This begs the question of whether there are advantages to one bias compared to the other in terms of the effectiveness and efficiency of developing ISR products. One could easily argue that to ignore context is to create an incomplete picture of an operational situation and may, for instance, result in mistaking a wedding party for an insurgent convoy. When processing resources are limited, however, it is difficult to say which kind of information is more important.

As will be discussed in the technical development section below, automated systems built to aid ISR collection may unintentionally build cultural bias into their algorithms, further obscuring contextual details for the Western analyst for the sake of increasing overall throughput.

Cultural Varaint	Effect	Population trends	Implications for ISR
Context/Object Bias	Eastern populations	Collectivist Eastern populations place a greater emphasis on context than individualist Western counterparts	**Perception.** Western analysts may be more likely to miss contextual details under time pressure than Eastern ISR analysts.
Comfort with ambiguity	Collective societies that seek harmony and compromise, whereas Individualistic societies value debate and believe in one correct answer.	Collectivist Eastern populations are more comfortable with ambiguity, than Western counterparts, are less comfortable with debate.	**Comprehension.** Eastern militaries may be more open to, and likely to consider alternate theories. This may mean they are less susceptible to confirmation bias. **Projection.** Decisions eventually must be made, and without debate the pros and cons of each possibility may not be explored.
Spatial vs Linguistic representation of numbers	Character based languages are represented in the spatial and pre-motor areas of the brain, whereas Arabic-based languages are represented in semantic processing regions	Eastern populations learn both character-based language and Arabic numeric system, whereas American populations learn language and numbers in the same representation system	**Comprehension.** Eastern analysts may have less cognitive load when processing numbers and language at the same time, but may have more cognitive load from processing numbers and spatial information at the same time.

Genetic variants related to attention dependent monoamine neurotransmitter systems suggest these variants could affect attentional mechanisms related to perception, however they have conflicting contributions to cognitive processes. For instance, Eastern populations have higher frequencies of the COMT(met) allele associated with greater attention control. Western populations have a higher incidence of CHRNA4(T) allele associated with false cue distraction. This may mean that Eastern analysts are better able to stay on task than Western analysts, which has both operational advantages and disadvantages. The ability to focus during stressful or high-paced operations would improve an ISR cell's ability to execute an intelligence collection plan based on a set of intelligence requirements. However, Eastern populations also have a higher frequency of MAOA(3R) which is associated with slower orienting to new informational cues. This may mean that Eastern analysis may have greater focus, but may also not be as quick to notice and incorporate new and unanticipated information.

COMPREHENSION.

Interpreting information once it is perceived relies on multiple kinds of memory processes. **Working and short-term memory** affect how much information one can 'juggle' in the mind, and thus how many incoming streams of information one can attend and process during the course of operations. Language structures may affect working memory capacity, and genetic variants related to working memory point to the involvement of dopaminergic and other monamine neurotransmitter systems in regulating working memory capacity. Additionally, **long-term memory** affects the creation and accuracy of the mental model analysts construct and through which they interpret new information.

> ***"… anything that influences what information is remembered or retrieved from memory also influences intelligence analysis"***
>
> ***- Richards Heuer,*** *The Psychology of Intelligence Analysis (p. 26)*

Working memory. One of the most influential cultural factors on working memory is language. A common index of working memory capacity is to test how many numbers a person can remember. Seven digits, plus or minus two is the most commonly cited average for healthy people. Chinese subjects often test better than Western participants on this type of task leading to the initial conclusion that Chinese students had greater working memory capacities than American and Western students. Studies later revealed that because the Chinese words for numbers have fewer syllables than English words, Chinese speakers could hold more numbers in their working memory at once. When they controlled for the number of syllables, the English and Chinese speakers performed similarly. Since working memory is also the system we use to perform mental computations, a reduced linguistic load would leave more working memory resources available for increasingly complex problems. In this way, **any ISR function that involves numbers – such as targeting with GPS coordinates – might be relatively more susceptible to working-memory related errors when performed in English than in Chinese.**

Chinese and English speakers also represent numbers in different regions of their brains, which has implications for processing multiple streams of information at once. Chinese speakers use visual processing and premotor brain areas to process numerals. In contrast, English speakers use language-processing areas to process numbers.[101] Some believe that abacus-based mathematical instruction in Chinese schools is the source of this difference because it teaches computation in spatial rather than linguistic terms. This is relevant because we have distinct working memory capacities in different information modalities (visual-spatial and linguistic). Spatial working memory is separable from verbal working memory. It is easier to remember the same number of items in two different modalities (three verbal, and three spatial items for instance) than it is to remember then within a modality (six verbal items). Likewise, it is more difficult to monitor two incoming streams of verbal information at the same time, but we can often manage to monitor one verbal and one visual stream without too much difficulty. This means that if Chinese speakers would have more interference from simultaneously monitoring a visual-spatial information stream and a numerical information stream than English speakers. Likewise, if English speakers use verbal areas to process numerical information, they would have more interference between verbal and numerical information streams. Depending on the nature of the ISR task at hand – whether processing SIGINT or IMINT for targeting purposes – this information would be useful for designing intelligent ISR platforms that de-conflict information across different working memory capacities in a culturally-specific way.

The distribution of genetic variants does not add much to the discussion of working memory related differences between Eastern and Western populations for a number of reasons. First, the differential frequencies of the few variants that have been linked to working memory suggest contradictory outcomes. Eastern populations have a higher frequency of the high-working memory associated COMT(met) allele, but also higher frequencies of the dopamine transporter variant (DAT1 UTR 10R) associated with lower high-load working memory capacity. Once again, the complexity of epistatic interactions (and yet unknown regulatory mechanisms)

[101] Yiyuan Tang et al., "Arithmetic Processing in the Brain Shaped by Cultures.," *Proceedings of the National Academy of Sciences of the United States of America* 103, no. 28 (July 11, 2006): 10775–80, doi:10.1073/pnas.0604416103.

limits our ability to infer much from the differential frequencies of gene variants among populations at all. Second, and as was mentioned earlier, researchers have tested the working memory capacities of both Eastern and Western populations, and after the influence of language is accounted for, there is no measurable difference between the groups.

TABLE 6: GENETIC VARIANTS LINKED TO WORKING MEMORY

Variant	Effect	Population Frequencies	Implications for ISR
CHRNA4 (C/T)	**CHRNA4(T)** T carriers are more distracted by false cues; do not benefit from accurate cueing	**CHRNA4(T)** European: 58% Han: 23-25% Japanese: 35%	Western ISR analysis may be more easily distracted by false cues and alarms, possibly making them less efficient in analyzing intelligence than Eastern counterparts.
COMT (Val158Met)	**COMT(met)** tend to perform better on working memory tasks, executive functions but also tend to have higher anxiety.	**COMT(met)** European: 52% Han: 71-74% Japanese: 71%	An Eastern analyst population with a greater incidence of COMT(met) may be better at persistent and monotonous ISR functions compared to a Western ISR population. They may also be more susceptible to the effects of anxiety (though anxiety related disorders occur at a lower incidence in Eastern societies).
DAT1 (UTR 10R)	**DAT1 (UTR 10R)** Those with two copies of UTR 10R have lower high-load working memory	**DAT1 (UTR 10R)** European: 63-76% Han:84% Japanese: 99% Russian: 88%	The higher incidence of the UTR10R in Eastern populations may mean a greater number of Eastern ISR analysts have trouble mentally juggling as many variables in high-load situations than Western analysts.
DBH (G444A)	**DBH(A)** Less automation bias and increased accuracy when working with automated decision aids.	**DBH(A)** European: 47% Han: 83-91% Japanese: 84%	Eastern populations may have a better sense of when to trust decision aids and when to consult additional sources of information when interpreting intelligence. The intelligence products may then be more

	Advantage in spatial working memory		accurate or complete than those produced in the US. A greater number of Eastern ISR analysts may have better memory for adversary and ally assets distribution on a map.
MAOA (3R)	**MAOA(3R)** carriers have less efficient attention control, and are slower to alert to new information	**MAOA(3R)** European: 32-35% Han: 61-65%	If Eastern analyst populations have a greater incidence of the 3R variant, more people in the population may be slower to notice new information and exhibit reduced ability to control their attention in a top-down manner.

Long-term memory. Long-term memory – or the ability to retain and recall information – is necessary for building a working mental model of the battlespace and the dynamics therein. The more historical data and experiential subtlety within a model, the more useful it is for recognizing critical indicators, interpreting and understanding the many dynamics of the battlefield and operational environments. Analysts with better long-term memory - in terms of accuracy, permanence, and recall – would be able to build and use more complex and detailed mental schema. Over time this contributes to experience, which is in the eyes of many ISR analysts, may be the important factor contributing to performance. The better long-term memory, the faster one can learn and build experience to guide future work.

There are at least three (and very likely hundreds more) genetic variants associated with long-term memory (KIBRA, PRNP, and BDNF, Table 5) with non-uniform distributions across Western and Eastern populations. Eastern populations have a higher frequency rate of two variants (KIBRA, PRNP) associated with superior long-term recall, but a lower relative frequency rate of the third (BDNF) compared to Western populations. Just as with short-term memory, genetic frequencies tell us very little about behavioral advantages in long-term memory. Nisbett's dichotomies and cultural influences, however, tell us more.

Cultural perspectives, influences and biases, heavily influence these schemas and as such, the subsequent intelligence products will reflect those perspectives. Mental model building is an iterative process, and as such previous intelligence prioritizes collection requirements and shapes how new data is interpreted and incorporated into the existing schema. This means that cultural tendencies to focus on objects, organize information by categories, and the preference for one correct explanation for events or phenomena are likely to shape the way Westerners view and interpret military relevant information. For instance, Eastern test subjects had more difficulty remembering objects when the backgrounds behind the objects were removed or changed than Western subjects even though there was no difference between groups when objects were presented with no contextual information at all[102] When building experience this could mean Western ISR cells are more likely to generalize across situations (similar to 'fighting the last war') irrespective of key contextual differences, and Eastern analysts may be less likely to recognize similar patterns across different areas of operations (AOs).

TABLE 7: Genetic variants associated with long-term memory

Variant	Effect	Population Frequencies	Implications for ISR & C2
BDNF (Val66met)	**BDNF(met)** Decreased working memory capacity, declarative memory and reduced brain activation during memory tasks	**BDNF(met)** Western:19% Eastern: 38-49%	If a larger percentage of Eastern people show slightly less effective BDNF-related memory formation, an analyst population reflecting the same distribution may not be quite as good at comparing incoming intelligence into memory-based constructs.
KIBRA (C/T)	**KIBRA(T)** Increased episodic memory and long term memory Decreased cognitive flexibility	**KIBRA(T)** European: 27% Han: 78% Japanese: 81%	A greater number of Eastern ISR analysts may exhibit related advantages in long and short term memory that would help offset the errors associated with information 'falling off the radar' (dropping from short term recall). The same difference may afford disadvantages in cognitive flexibility or multitasking necessary to juggle multiple forms of incoming intelligence and mission critical information.
PRNP	**PRNP(Met)** is associated with better long term memory	**PRNP(Met)** European: 63-66% Han: 96-99% Japanese: 98%	If Eastern ISR analyst populations have a higher incidence of PRNP(Met) they might on average have better long term memory function.

[102] Takahiko Masuda and Richard E Nisbett, "Attending Holistically Versus Analytically: Comparing the Context Sensitivity of Japanese and Americans.," *Journal of Personality and Social Psychology* 81, no. 5 (2001): 922, doi:10.1037//0022-35I4.81.5.922.

A related phenomenon is the influence that cognitive biases - such as mirror imaging, the recency effect, and confirmation bias – may have on intelligence analysis. Richards J. Heuer (Center for the Study of Intelligence) identifies, describes, and presents a model for overcoming such cognitive missteps in "The Psychology of Intelligence Analysis" (1999). Heuer's discussions are intended for the Intelligence rather than the Defense community, and though it is outside the book's scope to consider whether the biases are universal across cultures[103] his arguments and examples are useful for the present analysis. They show us areas in which differences in Eastern and Western perspectives may influence how things are conceived and remembered and how that influences the intelligence processes.

"Mirror imaging" is among the most well-known biases within analytic intelligence communities and is directly relevant to the question of how cognition differs between cultures. Mirror imaging is the tendency to falsely assume that others have similar values, motivations, and perspectives to one's own. The major challenge in avoiding this bias is identifying tacit assumptions in order to actively question whether others assume. There is evidence that collectivist values influence habits towards perspective-taking which could affect the tendency to mirror-image. In a study that paired Chinese and American subjects to play a perspective taking game, eye gaze behavior showed the Chinese subjects were more tuned to their partner's perspective compared to the American subjects. The Chinese subjects also almost always explicitly considered their counterpart's perspective when Americans often failed to do the same.[104] The authors interpreted this to mean that collectivism made the Chinese better perspective-takers. If so, this means they would also be less likely to fall victim to mirror-imaging. There was, however, no accuracy measure for those perceptions. In other words, collectivists may more often consider another's perspective, but it is unclear whether that means they have an accurate sense of what the other's perspective is. Rather, there is evidence that the ability to infer emotion from eye expressions is very consistent across Eastern and Western populations. A study comparing Japanese and white American subjects found that both groups are better at 'reading' emotions in people from their own culture than they are reading emotions in those from other cultures, but that there is no appreciable difference between the groups in terms of overall accuracy, nor in brain activation patterns.[105]

Indeed, It appears that other militaries, including the [redacted] still suffer from mirror imaging errors despite a putative increased consideration of another's' perspective. Writings regarding the American President's for instance, focus far less on his personality qualities and tendencies as

[103] This is not a critique; such analysis was outside the scope and purpose of the book.
[104] Shali Wu and Boaz Keysar, "The Effect of Culture on Perspective Taking.," *Psychological Science* 18, no. 7 (June 28, 2007): 600–606, doi:10.1111/j.1467-9280.2007.01946.x.
[105] Reginald B Adams et al., "Cross-Cultural Reading the Mind in the Eyes: an fMRI Investigation.," *Journal of Cognitive Neuroscience* 22, no. 1 (January 2010): 97–108, doi:10.1162/jocn.2009.21187.

an individual, and focus to a greater degree on the nodes of influence around him reflecting the [redacted] view of their own leadership structure in which the [redacted] President is far less important than the collective [redacted] leadership. Another example is North Korea's reaction to the American comedy film ('The Interview') depicting goofy entertainment news hosts who are asked by the CIA to assassinate Kim Jong Un. North Korea, not understanding that Western media is not government propaganda, assumed the movie was at least tacitly approved by the American government. In response, Un threatened retaliation if the movie was released.[106]

Though it is not clear why increased perspective taking does not equate to better perspective taking, one possibility may be the strong Eastern association with one's in-group and exclusion of those outside those circles. As a few [redacted] experts noted, the [redacted] in general have very little empathy for those they do not feel a connection to. One workshop participant described daily interaction on the street in [redacted] in which able-bodied adults will knock over the elderly to get a cab. Another described a situation in which a child laid injured and dying in the street after being hit by a truck. Despite many passing by, it was some time before anyone helped the child because no one knew him.[107] This sort of lack of empathy may be changing within [redacted] The latter example caused a public uproar in the [redacted] media and the [redacted] realizes this lack of cohesion and empathy is a challenge to their efforts to build centralized [redacted] nationalism among the broader population. It is doubtful whether those efforts will extend beyond [redacted] borders. Consideration of how others' views may differ requires empathy, so a lack of empathy for outsiders may limit the utility of increased perspective for avoiding mirror imaging.

Other cognitive biases and how they influence intelligence analysis may diverge between militaries. Confirmation bias, as a function of resistance to alternative theories, is one of these.

Confirmation bias and the dismissal alternative hypotheses. Confirmation bias is the tendency to believe in evidence that supports, and dismiss evidence that refutes, a favored theory. Subject matter experts (SMEs) consulted for the purposes of this project confirmed that this bias affects ISR functions and the quality of ISR products. One of the more public examples of confirmation bias affecting intelligence processes was Colin Powell's Weapons of Mass Destruction presentation to the UN in the months leading up to Operation Iraqi Freedom. Even though many disagreed on the decision to invade, most in the US were confident in the theory that Iraq had a robust and dangerous WMD capability. In support of that theory, American analysts searched for evidence of presumed mobile chemical weapons units and storage facilities. Each side of the debate pulled information that supported their position from the

[106] Sam Frizell, "Kim Jong Un Swears 'Merciless' Retaliation if New Seth Rogen Film Released" 25 June 2014 Time.com. http://time.com/2921071/kim-jong-un-seth-rogen-the-interview-james-franco/

[107] Participant, NeuroCognitive Divide Workshop. Scitor Corporation, Rosslyn Virginia, 3 June,2014.

resulting intelligence that Secretary Powell's presented to the UN. To those who believed Iraq had chemical and biological weapons, the evidence was damning (see Figure 16 for an example). However, to skeptics it was far from conclusive.

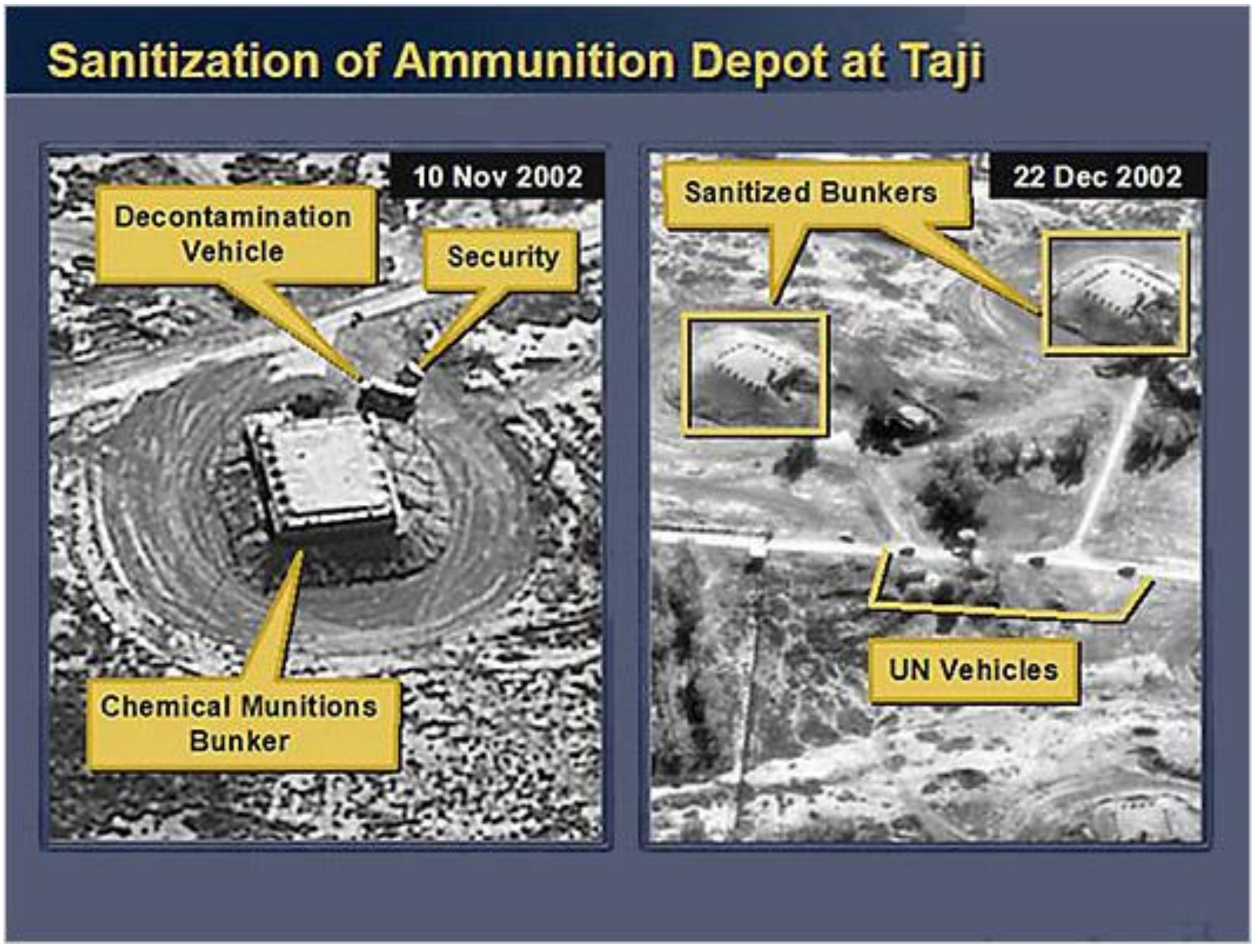

FIGURE 12: One of the images Secretary Colin Powel presented to the UN as evidence Iraq had a robust chemical weapons program and that it was sanitizing and hiding evidence of that capability prior to the arrival of UN inspectors. February 2003.

Exacerbating this issue is that US intelligence communities and consumers of intelligence tend to place a premium on the confidence in intelligence products, even though confidence does not necessarily reflect certainty. One can have a very high level of confidence that there is a 50% chance a coin will land heads-up, which would be accurate estimate of an uncertain outcome. Consumers of intelligence products may not realize it, but they prefer certainty over accuracy which would be the equivalent of preferring a report stating there is a 70% chance the coin lands heads-up even if that percentage it does not reflect reality. This bias towards certainty over accuracy means that good quality intelligence can be dismissed if it does not provide to a definitive prediction.

Certainty ≠ Quality

But what do these cognitive biases have to do with neurocognitive differences between Eastern and Western populations? It is possible that this tendency is worse among Western analysts due to individualist discomfort with ambiguity. The Eastern drive towards harmony applies to geopolitical and scientific theories as well; in Eastern cultures there is a tendency find compromise between opposing theories, or reasons that multiple theories are correct. The Western approach on the other hand, built on a tradition of debate, strives to determine which theory represents 'truth' and which is wrong. A classic example is the debate in early psychology over the relative importance of 'nature versus nurture'. Today we have come to realize that behavior is the product of the interaction of both nature *and* nurture, but not before a fair amount of disagreement among Western scientists on the subject, who still are often surprised that both theories could be correct.

The present question, however, is how does this difference in approach affect the respective intelligence products of Eastern versus Western ISR efforts? It is likely that Western ISR analysts may be less willing to consider alternative theories, and would thus be more likely to miss or dismiss key pieces of information that do not fit into prevailing schema. Might this lead to a greater number of outright 'intelligence failures' or unexpected outcomes?

Confirmation bias in the West also means that once a theory is accepted, more information is needed to overturn the theory than was used to build it in the first place. Here again, the Eastern tendency to find truth in multiple theories may mean that less evidence is required for decision makers to consider options. While it may be advantageous for an ISR cell to entertain multiple models, ultimately it must decide on one to make decision. In such cases, the debate-avoidant Eastern approach may mean [redacted] counterparts spend less time questioning assumptions and fully discussing alternative courses of action and their potential outcomes. Indeed, one [redacted] expert described the [redacted] decision-making process as 'highly automatic' that leaves no room for subjective judgment.[108]

Even Heuer's description of intelligence analysis is indicative of a Western approach. Heuer describes a model that "defines the *categories* for filtering information in memory and retrieving it on demand" (emphasis added). An Eastern approach would focus on *relationships* instead of categories, which is reflected in [redacted] approaches to collection. There is a heavier

[108] Participant, NeuroCognitive Divide Workshop. Scitor Corporation, Rosslyn Virginia, 3 June,2014.

emphasis in the [redacted] on examining networks of people – who worked with or studied with whom, and where. [redacted] experts have gone as far as to describe the [redacted] as "obsessed" with social network analysis.[109] Professional and open networking sites like LinkedIn are likely very attractive to Eastern analysts for this reason. This may also, however, lead Eastern analysts to overestimate the importance of those relationships for Western decision-making processes. This is difficult to determine without access to [redacted] intelligence products.

Projection

The last element necessary for building accurate and useful situational awareness is projecting how dynamic elements within the current situation will affect future outcomes. This aspect of the ISR process may be influenced by cultural views of agency, causality and tendencies towards action.

The individualistic belief that people have control over themselves and their environment means that the US military (and Western ISR cell) has a greater sense that its action can control the battlefield compared to Eastern collectivist views. Indeed, US commanders strive to 'set battle tempo' that establishes an offensive rather than reactive pace in their operations. Neurocognitively this difference in perspective results in minor differences in neural function relating to causality. In an fMRI study examining [redacted] and American concepts of causality found that, unlike concepts of self and other, cognitive processes determining causal attribution activate very similar brain structures in both populations.[110] The [redacted] group did show additional activation in regions related to processing contextual details. While both groups agreed on the root cause of each causal relationship depicted during the study, the [redacted] group more often considered how contextual details shaped the event. This suggests that [redacted] judgments about causality include a greater number of variables than Western judgments. If the [redacted]s ISR process follows this pattern, cells would likely have richer mental models of the operational situation and may include more variables as information is fused and packaged for centralized decision-makers. The neural cost of considering a multitude of marginally important details might, impose additional cognitive workload on bandwidth-limited analysts though heavy automation in [redacted] operations may relieve this load if analysts are not required to make judgments from the information gathered.

Differences in a sense of personal agency, which likely influence command and control processes (discussed next), may also affect intelligence, reconnaissance, and surveillance. If one

[109] Participant, NeuroCognitive Divide Workshop. Scitor Corporation, Rosslyn Virginia, 3 June,2014.
[110] Shihui Han et al., "Functional Roles and Cultural Modulations of the Medial Prefrontal and Parietal Activity Associated with Causal Attribution," *Neuropsychologia* 49, no. 1 (January 2011): 83–91, doi:10.1016/j.neuropsychologia.2010.11.003.

believes that he has the power to control an unfolding situation, he may feel a greater impulse or even responsibility to act. In an ISR context, this may mean an analyst is more likely to seek information in non-traditional sources or diverge from pre-determined information gathering plan as new information arises. In this way Western ISR is likely more adaptive than Eastern [redacted] counterparts. To this point, we will consider in the next section how neurocognitive differences may affect operational decision-making and military action.

COMMAND AND CONTROL (C2)

The [redacted] and Western militaries approach Command and Control (C2) in distinct ways, but since deciding how and when to take action on the battlefield is heavily reliant on cognitive processes it may also be shaped by factors that affect neurocognitive processes. John Boyd's "Observe, Orient, Decide, Act" loop, or "OODA-Loop"[111] summarizes the (undoubtedly Western) cyclical decision-making processes that underlie C2 (Figure 14). A major goal among US commanders is to set the pace of operations by operating inside the enemy's decision cycle by observing, orienting, deciding and acting faster and more effectively than the adversary, thereby setting the tempo of operations. In cognitive terms this involves perceiving, assessing/interpreting, establishing value/risk in order to make a decision, and effectively executing that decision. Speed is a priority in all steps, and when working quickly people tend to revert to habits and heuristics, which are influenced by cultural factors. Like ISR, a good portion of the C2 process is heavily reliant on how information is encoded (perceived) and the planning process (projection). Because the perception and comprehension aspects of C2 (i.e., observe and orient) overlap with ISR, and since we have already discussed those functions above, this section will focus predominantly on decision-making (deciding and acting). In this section more than the others we will consider not just regional-cultural, but specifically *military*-cultural differences between East and West. From a cultural perspective, the comparative differences we see in [redacted] command styles reflect collectivist value structures. If so, it may be more difficulty for [redacted] commanders to adopt the principles embedded in the [redacted] aggressive modernization strategies - which are notably more individualist in nature.

Centralized and Decentralized Decision-Making. Though the [redacted] efforts to modernize have included efforts to create more dynamic less centralized command structure, compared to Western militaries the [redacted] has a far more centralized approach to command, in which decision-making is a high-level group process involving heavy political involvement and oversight. The US military, on the other hand pushes decision-making as far down the chain of command as possible. The US system adheres to von Moltke's view that because no plan survives first

[111] Boyd, John The Essence of Winning and Losing, 28 June 1995. www.danford.net/boyd/essence4.htm

contact, small unit commanders must be empowered to execute commander's intent rather than follow explicit orders if they are to adapt to changing situations. In stark contrast, and even within the [redacted] view of modernization, decision-making is highly automatic in the [redacted] partly to promote efficiency but also to eliminate the influence of "subjective" processes. Technical development for C2 is highly redundant to prevent disruption during combat operations and strives to improve "command automation [redacted] Centralized authorities construct pre-determined extensive and detailed military plans, which they distributed to lower units. The [redacted] view, creating and distributing pre-determined plans for *every imaginable scenario* enable quick action and eliminates the need to adapt on the fly as much as possible. A pre-determined plan will also establish a decision cycle (or rather execution cycle, since most decisions have been made) irrespective of enemy actions. The [redacted] bases this planning on what they see as quick and overwhelmingly decisive strategies; as a result detailed plans rarely extend beyond a few days. Units are expected to execute these plans largely without question, and though are now encouraged to make certain ad hoc tactical decisions, compared to the US style small unit decision-making remains highly constrained.

[redacted] has acknowledged that informationalized warfare is non-linear and requires some level of tactical flexibility, and has instituted "fuzzy authorization training" to teach commanders and soldiers how to make more decisions in an ad hoc manner.[114] The concept of "fuzzy decision making" comes from the field of artificial intelligence (AI) and neural network modeling; the [redacted] adoption of it as a guiding principle for permitting tactical adaptation is revealing. Fuzzy models are less deterministic than strict rule models because they add probabilistic weights to logical relationships, *but they are still built on underlying rules.* In the Western view, 'outside-the-box' thinking and adaption emphasizes an almost rule-absent approach of applying training, skills and principles to execute commander's intent. This example demonstrates that although the [redacted] is modernizing C2 in what appears to be a Westernized direction, that the traditional military culture is still embedded.

Group-level decision-making is another hallmark of C2 in the [redacted]. At a minimum at least two people are involved in all command decisions: a military commander and a political officer. This type of arrangement would be aversive to US commanders. In their view, decision-making "is stressful enough without having a politician looking over [their] shoulders, questioning [their] decisions."[115] In a collectivist culture, however, it is likely more stressful to bear singular responsibility for decisions than it is to have to vet those decisions with political leadership

[112] Roy Kamphausen, Andrew Scobell, and Travis Tanner, "The' People' in the PLA: Recruitment, Training, and Education in China's Military," 2008.
[113] ibid. pg 59.
[114] ibid. pg 65.
[115] Comment by a retired USN submarine captain. Neurocognitive Divide Workshop, June 3, 2014

since potential failures are shared. These differences have implications for how and when plans and decisions are made within each respective military, which in-turn can influence cognitive states of the decision-makers.

Trusting the small unit commander to adapt to execute commander's intent means he will be making operational decisions under various battle-related pressures (or performance disruptors, as discussed above). Forward commanders are usually sleep-deprived and under a great deal of stress during operations, meaning their executive cognitive processes are compromised during the time the US asks them to make high-stakes decisions. From this perspective it seems reasonable to think well-rested and experienced strategists with a central view of the entire operational picture would make better decisions than the forward commander. To the [redacted] it may seem unreasonable to think a young unit leader can weigh the many complex dynamics under battle-imposed time-pressure and develop a good response. If a scenario plays out exactly as the [redacted] imagines it might, then the [redacted] may indeed have a more cohesive plan based on more thorough decision making processes, executed efficiently by unquestioning forces.

If, on the other hand, situations unfold differently than the [redacted] anticipates, the lack of familiarity with fast decision-making under stressful conditions means the [redacted] C2 would be at a neurocognitive disadvantage. First, the centralized command structure means that when situations change, requests for centralized direction will lead to much slower decision-making. Units may find themselves in situations where they are required to act, absent direction from centralized command. Within efforts to modernize, units are encouraged to adapt but it is unclear how much latitude they have within that guidance. "Ad hoc" decision-making [redacted] may mean execute a slight variation of the most appropriate even if less-than-ideal plan until guidance arrives. If commanders attempt to adapt, like US commanders, [redacted] forces would have to make decisions during compromised (fatigued, stressed) states. US commanders will also find the process of making decisions on the fly to be less aversive than units in a culture where acting independently is discouraged or even shameful. Moreover, because the US units train to make decisions under stressful sleep-deprived conditions, and experience reduces cognitive load (see the section on training, below) the US commanders will putatively have more residual cognitive capacity to plan on the fly than would [redacted] counterparts in a similar scenario.

Choosing a particular course of action is another source of possible neurocognitive divergence. It is possible that the ability to see multiple 'correct' options could undermine a group's ability to choose one above another leading to hesitation or perseveration. This would be more likely in a scenario in which subordinates cannot communicate with central command. As was discussed earlier, it is rather more likely that debate-avoidant cultures who discourage subordinates from offering dissenting views, would be less likely to question assumptions behind group-level (and therefore 'group-think' vulnerable) decisions. Some have proposed that this tendency has hampered scientific development in China; it may also be that this element of [redacted] Eastern culture may undermine the [redacted] involved efforts to create clever – yet unscrutinized - strategies. While the [redacted] might have a C2 advantage in scenarios that unfold exactly as they anticipate, purely due to military cultural approaches the US is likely to have more cognitively stress-resistant and experienced decision-makers up and down its chain of command if conflicts diverge from the expected path.

***Restraint*.** As was mentioned in the introduction, Hofsteade's Power Distance Index (PDI), or measure of "the extent to which the less powerful members of organizations and institutions (like the family) accept and expect that power is distributed unequally (Figure 7),"[116] In this way, individualism/collectivism also influences how those in power exert their power. In independent cultures, those with power have a greater tendency to act assertively, whereas those in interdependent cultures show greater restraint with more power. This suggests that the highest-ranking military commanders in the [redacted] would exert more restraint in action over subordinates than an American counterpart. While interesting, it is not clear how this would manifest on the battlefield. Would that commander also show more restraint against an adversary? This is unlikely given that the measure is related to one's level of connection to others, and it is unlikely they would feel interconnected to an adversary in a way that would garner restraint. It may be that the reported lack of empathy [redacted] have for those outside their in-group would translate into *less* restraint when acting against an adversary regardless of one's hierarchical position in the [redacted] History would support the latter idea, which is a reminder that though cultural studies provide an interesting layer of texture to our understanding of societies other than our own, that their findings may or may not generalize beyond the contexts in which the data were gathered.

Uncertainty and Ambiguity In C2

Despite ongoing attempts to build networks of sensors, tools and displays to create and maintain timely situational awareness (SA), the proverbial 'Fog of War' ambiguity and uncertainty persists in C2. Uncertainty about potential or future threat is a well-documented source of anxiety. Anxiety is also distinct from fear: fear is a response to immediate or impending threat; anxiety is a response to potential or uncertain threat that is similar to worry.

[116] Chen-Bo Zhong, Joe C. Magee, William W. Maddux, Adam D. Galinsky (2006), Power, Culture, and Action: Considerations in the Expression and Enactment of Power in East Asian and Western Societies, in Ya-Ru Chen (ed.) *National Culture and Groups (Research on Managing Groups and Teams, Volume 9)*, Emerald Group Publishing Limited, pp.53-73

Since most commanders are slightly if not significantly distant from the front lines, anxiety is likely to be a more significant factor than fear for affecting the neurocognitive mechanisms behind C2 decision-making. The brain responds to anxiety similarly than it does to fear, by releasing stress hormones that in the short term narrow attention and increase distractibility. Unlike fear, however anxiety is non-specific and persistent for some, meaning it is more likely to lead to chronic stress related dysfunctions such as impaired long term memory formation, and hormonal dysregulation (see acute and chronic stress sections, above).

This kind of operational uncertainty may cause greater anxiety among commanders in a culture that is less comfortable with ambiguity. In ISR this manifests in a preference for certainty of intelligence estimates over accuracy (discussed above). It may also be why in command and control, US forces see setting the pace of operations and maintaining an offensive posture as an inherent good. Even if the action taken is less than ideal, taking action reduces ambiguity and would putatively reduce the anxiety associated with the situation. A correlate of anxiety is rumination over elements outside one's control; attempts to control a greater portion of the possibilities – or to shape the battlefield – may be a response to Western discomfort with ambiguity. If Eastern militaries, in contrast, have a greater acceptance that certain things are beyond their control, [redacted] commanders may suffer less ambiguity-related anxiety compared to those in US military structures.

A certain level of ambiguity-related anxiety is both reasonable and expected during operations, but some individuals are less resilient in the face of that uncertainty. Questions of whether civilians are occupying a target location, or if the pending decision will send a forward unit to their death are common variables commanders must weigh when deciding how to employ their assets. Maladaptive responses to such pressures includes fixation with things outside one's control to the point of inaction, and some are more prone to this type of freezing behavior. Trait anxious people exhibit judgment biases that overinflate both the probability of negative events and the cost of those events if they occur. They are also hyper-vigilant and distractible, and waste time and energy worrying about uncontrollable factors rather than focusing on factors they can affect. Such disruptions in attention control are related to 'interpretation bias' or the tendency to interpret ambiguous stimuli as threatening, such as mistaking a walking stick for a weapon. Psychiatrists believe that this is at least partly the result of indiscriminant activation of the threat center of the brain (the amygdala), which undermines the ability to learn safety cues.[117] It also points to deficient executive emotional regulation. Even the most elite soldiers feel a need to engage in one of the three "F"s (feed, fight or fornicate) after a

[117] Dan W Grupe and Jack B Nitschke, "Uncertainty and Anticipation in Anxiety: an Integrated Neurobiological and Psychological Perspective," *Nature Reviews Neuroscience* 14, no. 7 (June 20, 2013): 488–501, doi:10.1038/nrn3524.

period of extreme stress[118] to release emotional pressure. Those vulnerable to ambiguity-related stress often respond with combative and aggressive behavior that undermines executive cognitive processes.

There are two major behavioral outcomes of this sort of maladaptive response to ambiguity and threat reactivity: avoidance and heightened reactivity. In the former, individuals attempt to reduce fear by ignoring or avoiding the situation. In a C2 context, this would contribute to general indecisiveness and perseveration; slowed decision response times would undermine the goal of operating inside the enemy's decision cycle to set the pace of operations. Heightened reactivity on the other hand, leads to heightened startle response (jumpiness in response to sudden events) could lead to over-reaction such as a sudden trigger-pull, or disproportionate use of force.

Predisposition to anxiety and threat reactivity would contribute to these sorts of maladaptive responses to ambiguity and uncertainty in military contexts. There are three genetic factors that may contribute to this kind of hyper-reactivity. The COMT(met) variant of the COMT(Val158Met) polymorphism has been associated with increased cognitive performance at baseline but increased anxiety under stress and negativity bias.[119]

Eastern populations have greater relative frequencies of three different factors that relate to threat attention bias, anxiety-related hypervigilance, and increased emotional memory compared to Western populations, yet it is not clear that this necessarily would lead to more erratic decision making behavior among [redacted] commanders. In isolation, the frequency of these anxiety-related factors suggests that Eastern populations may be more susceptible to anxiety disorders as well however anxiety disorders are not as frequent in Eastern populations compared to Western populations. Collectivism is also negatively associated with anxiety disorders[120] suggesting that that close familial and community relationships may be protective even despite potential genetic predisposition.

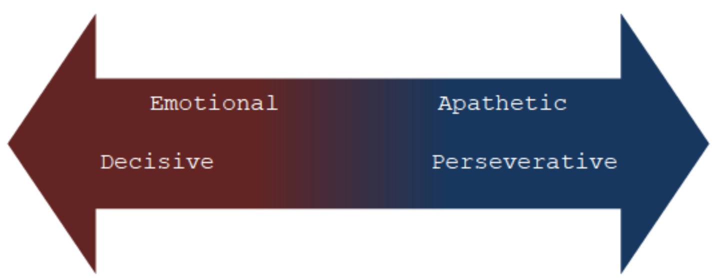

FIGURE 13: The relationship between emotional involvement in decision-making.

[118] Interview, Instructor, Special Forces Assessm

[119] Leanne M Williams et al., "COMT Val108/ nd Negativity Bias," *NeuroImage* 53, no. 3 (November 15, 2010): 918–25, doi:10.1016/j.neuroimage.2010.01.084.

[120] Chiao and Blizinsky, "Culture-Gene Coevolution of Individualism-Collectivism and the Serotonin Transporter Gene."

One could argue that Eastern cultural emphasis on restricted emotionality is a response to heightened sensitivity to emotional stimuli. If emotional responses are more aversive to a greater portion of the population, that population may prioritize cultural habits – such as seeking harmony and avoiding conflict - that minimize emotional reactivity. Neurocognitive evidence does not support this view. Eastern populations have been shown to be better at actively suppressing emotional responses to unpleasant images (see between 2000-3000 ms in Figure 16).[121] The findings did not show any difference in initial reaction to the stimuli

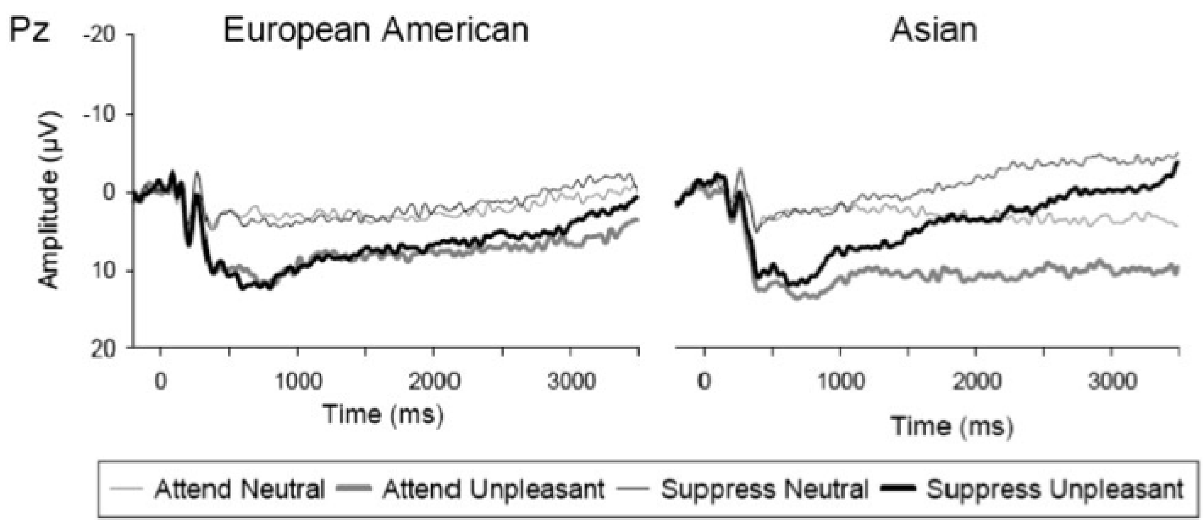

FIGURE 14: Asian participants were able to bring neural responses (thick black line) back to baseline within seconds when asked to suppress their reaction to adverse images. From Murata, et al., 2010.

(between 0-1000 ms in Figure 16), suggesting Easterners are no more sensitive to adverse images than Westerners but they are better at restraining their reactions to emotionally-arousing situations.

This suggests that while both groups may respond in the same way initially to aversive situations that the [redacted] may be able to control their emotional reactions to a greater degree and thus limit the stress-related hormonal responses that undermine executive cognitive function. This could mean emotive American bluster may be counter-productive for the ideal logical, emotion-free decision-making process for which Western culture strives. On the other hand, Antonio Damasio has demonstrated that decision-making is close to impossible without at least some emotional involvement.[122] Those who have suffered damage to emotional regions of their brains become clinically indecisive, perpetually debating between options. This is, of course, an extreme example, but it is also well observed that the opposite - heightened

[121] A Murata, J S Moser, and S Kitayama, "Culture Shapes Electrocortical Responses During Emotion Suppression," *Social Cognitive and Affective Neuroscience* 8, no. 5 (June 14, 2013): 595–601, doi:10.1093/scan/nss036.
[122] Antonio Damasio, *Descartes' Error*, (Random House, 2008).

emotionality - leads to reactionary behavior. On a spectrum of emotional reactiveness then Western emotionality may contribute to increased decisiveness - or rashness, depending on the context - in decision making in C2 environments. [redacted] commanders, in contrast, may be better able to control their emotional responses even if they have less experience making operational decisions.

	COMT(val158met)	ADRA2B	TPH2
High anxiety variant and population frequencies	**COMT(met)** European: 52% Han: 71-74% Japanese: 71%	**ADRA2B deletion** European: 28-33% Han: 46-48% Japanese:31-35%	**TPH2(T)** European: 21-25% Han: 52-56% Japanese: 50 %
Related cognitive functions	• Increased negativity bias • Increased anxiety under stressful conditions	• Increased emotional memory • Increased response to threatening images • Increased accuracy for detecting threat • Increased and indiscriminant awareness for potential threat	• Increased reactivity to emotional stimuli • Increased harm-avoidance behavior
Theoretical effects during operations	Genetic frequencies suggest Eastern populations should show: • Increased threat-related distractibility • Inability to focus during a firefight or other combat operations. • More erratic decision-making as a result of either avoidance or hyper-reactive behavior. • Increased memory for emotional stimuli (events), and • Vulnerability to combat –stress related disorders.		
Behavioral Findings	Eastern populations exhibit fewer anxiety related disorders, combat-stress related psychological injury, and no difference in threat-related distractibility. Learned and culturally enforced emotional regulatory strategies may instead manage hormonal stress responses to adverse events in combat and preserve executive decision making in the face of stress.		

Risk taking. Cultural differences in risk taking may affect the which courses of action commanders choose to pursue, but in this instance, as in others, biological pre-disposition to risk taking behavior may not be as informative as understanding the culturally-bound

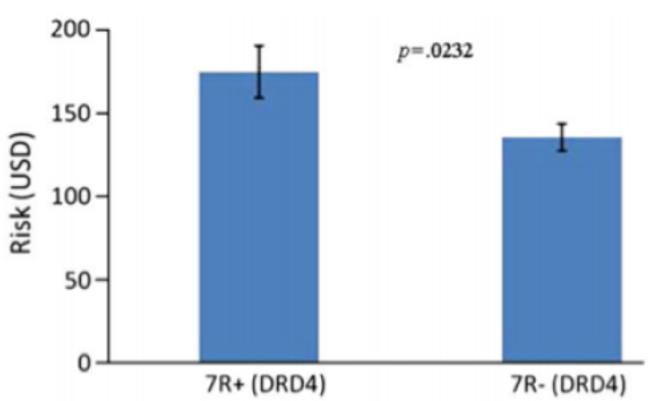

FIGURE 15: Those with the 7R+ long repeat variant of DRD4 are willing to risk more money on average than those without the long variant. From Dreber et al., 2009.

values that enter into each group's respective risk calculus. The experimental evidence from gene-culture theories, from psychology and from historical example is often contradictory towards characterizing Western and Eastern populations cleanly in terms of relative risk-tolerance. For instance, associations between the genetic variant of DRD4 and financial risk taking behavior would suggest that Eastern populations would take less financial risk than Western populations. The DRD4(7R+) long variant has been linked to larger wagers in gambling games (Figure 17)[123] and to greater migratory behavior in population wide-analysis (Figure 18).[124] The long variant of DRD4 is nearly non-existent in Eastern populations (Han < 0.5%, Japanese 1%) and occurs most frequency in Western groups (Europeans: 16-18%). Both of these findings would suggest that East Asians would on average be more risk avoidant than Westerners. Indeed, both Chinese and American study participants guessed the same. But when asked to play a gambling game, Chinese participants placed larger and more risky bets on average compared to the Americans.[125] Despite both groups believing Easterners were more risk avoidant, it turns out the Eastern group made far riskier financial decisions. This finding has since been replicated and is supported by real-world (non-laboratory) observations of Chinese gamblers in Macau, who make larger bets on average than their Western counterparts.[126]

In response to this finding, Hsee and Weber proposed the "Cushion Hypothesis" which attributes greater financial risk tolerance in Eastern collectivist populations to the security (i.e., cushion) that comes from having a stronger social support regardless of financial loss. In another study examining American and Chinese proverbs, they found

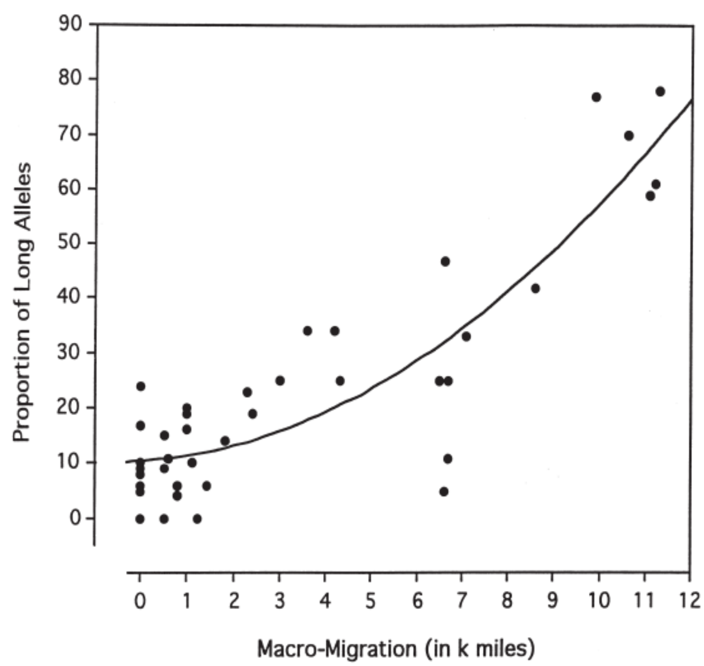

FIGURE 16: Association between frequency of long DRD4 alleles and population level migratory behavior. From Chen et al., 1999.

[123] Anna Dreber et al., "The 7R Polymorphism in the Dopamine Receptor D," *Evolution and Human Behavior* 30, no. 2 (March 1, 2009): 85–92, doi:10.1016/j.evolhumbehav.2008.11.001.

[124] Chuansheng Chen et al., "Population Migration and the Variation of Dopamine D4 Receptor (DRD4) Allele Frequencies Around the Globe," *Evolution and Human Behavior* 20, no. 5 (1999): 309–24.

[125] Christopher K Hsee and Elke U Weber, "Cross-National Differences in Risk Preference and Lay Predictions," *Journal of Behavior Decision Making* 12 (April 9, 1999): 167–79.

[126] JMY Loo, N Raylu, and TPS Oei, "Gambling Among the Chinese: a Comprehensive Review," *Clinical Psychology Review*, 2008.

that Chinese proverbs advocate financial risk taking to a greater degree than American proverbs. Chinese interpretations of proverbs regardless of national origin were also riskier than American interpretations.[127] These latter findings – in both cases – did *not* extend to the social domain, indicating risk aversion may be domain dependent. In other words collectivists may be less risk-tolerant if their social relationships rather than financial assets are at risk.

What different cultures interpret as risky in the first place is also highly variable, as historical examples illustrate. In one [redacted] expert's view of the Sino-Soviet border conflict of 1969, the decision the [redacted] made to attack Soviet soldiers along the Eastern border was enormously risky given the heightening nuclear tensions of the day. From a Chinese perspective, however, the risks of not acting to reclaim what the PRC describe as annexation of Chinese lands –appearing weak in defending the nation's border and an inability to manage the Chinese Uyghur population – and what it meant for controlling China internally, was far greater than increased tensions with the Soviet Union.[128] In cultural terms, it may be that the PRC's concern about the reaction of its in-group (i.e., the national population) contributed to its decision to grapple with a nuclear-armed world power.[129]

These collective findings regarding risk tolerance have a few key implications for understanding neurocognitive differences in command and control and military decision-making. First, in this example, like many others, predictions based on genetic allele frequencies give us little predictive power over population level trends in decision-making. Second, common assumptions regarding [redacted] and American risk-tolerance may not reflect actual behavioral patterns in certain contexts. Third, culturally –bound value structures (i.e., the emphasis placed on social relationships, and status within one's in-group) may be a greater motivating factor for the [redacted] and [redacted] than Western analysts may appreciate because collectivist cultures rely on those relationships to a greater degree than financial assets.

Overall, neurocognitive differences as they apply to command and control are most influenced by factors associated with military cultural practices.

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[127] EU Weber, CK Hsee, and J Sokolowska, "What Folklore Tells Us About Risk and Risk Taking: Cross-Cultural Comparisons of American, German, and Chinese Proverbs.," *Organizational Behavior and Human Decision Processes* 75, no. 2 (August 1998): 170–86.

[128] Participant, NeuroCognitive Divide Workshop. Scitor Corporation, Rosslyn Virginia, 3 June 2014.

[129] The Sino-Soviet border conflicts were, of course, far more complex than this simple interpretation and have been the subject of much analysis from American, Chinese, and Soviet sides.

Training & Selection

Regional cultural and military cultural differences between the US and [redacted] approach to training interact with neurocognitive processes to shape the learning processes and subsequent operational effectiveness. The traditional [redacted] educational style is both rote and lecture-oriented compared the Greek-inspired Socratic debate-driven styles of the West, and permeates the educational system from grade school through military post-graduate education. Relatively recent changes in historical [redacted] political attitudes towards military strategy have driven many changes in training and selection over the past twenty years. Modernization strategies within the [redacted] have pushed the [redacted] Professional Military Education (PME) towards decidedly more Western style of training. [redacted] "two transformations" was a notable turning point in this process, which emphasized: 1) quality in personnel over quantity; and 2) capability in what has become known as 'informationalized' warfare.[130] Since then the [redacted] has sought to recruit and promote more educated members, has shifted military education curricula towards modernized principles emphasizing technological expertise and advanced strategic thought (even going as far as to encourage debate and creativity), and has included more sophisticated simulation and virtual training methodologies.

While the trajectory of this trend is towards more Western style of training, the [redacted] and its members are still deeply embedded in collectivistic values. Thus, it is very likely that the [redacted] version of debate, for instance, would be less polarized or more formalized debate compared to that seen in Western military colleges and post-graduate schools. Likewise, despite overt efforts to increase technological capabilities and weapons systems, commanders have to encourage their units to use new technological systems[131] (though it is not clear whether this resistance among the ranks is due to a general lack of familiarity with computerized systems or a reflection of the quality of the systems themselves). This means that [redacted] modernization will likely develop in distinctly Eastern ways and as we consider neurocognitive differences that result we will assume certain collectivistic values and drivers persist –such as conflict avoidance, and emphasis on social relationships – even if [redacted] modernization feels Westward leaning.

Neuroscientists and psychologists agree that small differences observed in the lab such as these will magnify cross-cultural differences over extended learning periods.[132] The degree to which one will avoid conflict even in the form of educational debate, for instance, or think of mathematical concepts in spatial ways, would be difficult habits to overcome. Just as a person's

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[130] Kamphausen, Scobell, and Tanner, "The' People' in the [redacted] Recruitment, Training, and Education in China's Military."

[131] Participant, NeuroCognitive Divide Workshop. Scitor Corporation, Rosslyn Virginia, 3 June,2014.

[132] Angela H Gutchess and Allie Indeck, "Cultural Influences on Memory," in *Progress in Brain Research*, vol. 178, Progress in Brain Research, (Elsevier, 2009), 137–50, doi:10.1016/S0079-6123(09)17809-3.

native language establishes a framework through which he will learn other languages, the fundamentals of early Eastern and Western educational practices will affect subsequent education and training regardless of efforts to shift pedagogic principles.

Cultural influences on learning mechanisms: attention, memory and semantic representations. Differences in attention and information organization between Eastern and Western populations will also affect how people remember and accumulate knowledge over time. Within laboratory environments Eastern participants show better memory for contextual details but more difficulty remembering details when contextual information is absent. As a result [redacted] students may be less comfortable generalizing observations across different situations as contexts change, while Western students may fail to appreciate multiple contributions to historical events in favor of single causal explanations, which would affect how operators apply what they learn to real-world operational and combat scenarios.

As discussed earlier, differences in symbolic structures like language and math also affect how the brain encodes and uses that information. Abacus-based mathematical methods are inherently more spatial than Western verbal/symbolic methods. As a result [redacted] students represent mathematical relationships in their visuo-spatial regions while Western students represent the same relationships in their verbal and language processing regions. This may or may not have implications for overall advantages in mathematical problem solving, but it does mean that numbers compete with verbal information for limited working memory in Western-educated students, and compete for spatial working memory resources in Eastern students. This culturally-bound influence would affect, for instance, each group's ability to multitask across verbal and spatial domains. A[redacted] student may have less trouble speaking while also solving mathematical equations, whereas a Western student may find it easier to solve math problems while navigating a visuo-spatial maze. This may influence US submarine operators, for instance, who learn to compute mental calculations regarding both speed and distance using visuo-spatial cues. If the [redacted]hinese use similar methods and think about math in a more spatial way than Westerners, they may be able to compute similar calculations more quickly and reliably compared to an American who has to connect linguistic mathematical symbology with spatial and geometric information.

As operations become more 'informationalized' and based on computerized systems to aggregate and disseminate information up and down the chain of command, how those data are coded, fused and presented will affect how they load the user's cognitive systems. A great deal of work in US weapons systems is devoted to optimizing user interfaces to de-conflict cognitive bottlenecks. This includes distributing information delivery across multiple sensory

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systems (auditory and haptic in addition to visual) and presenting information in spatial, numerical and verbal formats that promote awareness. Since the [redacted] acquires much of its technology by adopting and adapting systems developed by the West, it is probable that the [redacted] is incorporating systems and simulators optimized for Western cognitive styles. If Eastern number systems change the cognitive bottlenecks (between spatial and verbal areas) then the Western optimized systems may not be as useful for de-conflicting information processing for Eastern cognitive styles.

Individualized methods. Militaries have historically taken a one-size-fits-all approach to personnel, from boot camps to standardized uniforms. As units become more specialized or elite, both [redacted] and US military training practices become more tailored to the unit's specific missions and needs, and selection scrutinizes individual capabilities. Beyond these similarities and in a very literal sense, [redacted] pedagogy follows collectivistic values compared to more individualized approaches of the US system. In the US individualized specialization is extending beyond tier-one units to less-specialized operators. Recent strategic-level visions with the Department of Defense's research community stress not only individualized physical training regimens but also fine-tuned computer based training methods that adapt to learning styles. The Army and Air Force Research Laboratories (ARL and AFRL, respectively) are currently seeking ways to develop simulators and platforms that adapt to the user's capability and track their progress. These labs are also seeking ways to train based on each individual's acute and chronic stress responses, and are incorporating personalized adaptation timelines to hypoxic environments. Though the [redacted] is increasingly incorporating simulators into their training, it is motivated to a large degree by the relative cost compared to live training exercises and a need for more training hours in general. It is unclear if it has made similar investments towards individualized methods but it is less likely, especially if cost is a major driver for turning to simulated training systems.

Train as you fight. An increase in simulation in the East does not necessarily mean an increase in training overall. Rather, some believe it will mean fewer live training exercises for [redacted] units.[133] Western militaries, on the other hand, and the US in particular set the bar for training hours on "training as they fight." The US places a greater emphasis on training in general, and live training for educational purposes (as opposed to politically-driven demonstrations of might) compared to the [redacted] The [redacted] push to increase [redacted] fighter pilot hours to meet the averages of US fighter pilots illustrates that even the most high-priority operators in the [redacted] will not get the same level of live training without targeted efforts to do so. Live training is also

[133] Kamphausen, Scobell, and Tanner, "The' People' in the PLA: Recruitment, Training, and Education in China's Military."

limited in some instances by the [redacted] resistance to have units train with actual weapons systems to limit the wear and tear on expensive equipment.

A lower general level of training hours overall, and live training in particular, places a large cognitive burden on the operators during a time when, as discussed above, cognitive capacity is limited by the stress of combat. If a crew has not trained with a system it will not have created what some refer to as 'motor memory' or spatial and tactile familiarity with the equipment; in the absence of such familiarity the operator will need to recruit more cognitive resources to complete the same task as a better trained counterpart. Similar to learning to drive, at first one must consciously guide themselves through the many steps involved (check mirrors, shift, release clutch, depress pedal, etc.). As a result, the novice tends to perform those steps sequentially. The experienced driver, on the other hand, performs all of these functions in parallel, more efficiently, and maintains cognitive resources free to consider, for instance, the multiple routes he might take to avoid traffic. The novice has little additional capacity to consider anything beyond the driving process, including unanticipated events. Similarly, if [redacted] units have not developed familiarity with their systems, they will have limited cognitive reserve for recognizing and adapting to changing battlefield situations as they unfold. Greater time training and more variability in training scenarios will translate directly into to more automatic, adaptive system operation.

Similarly, it is unclear if the [redacted] institution of "fuzzy authorization training" to teach commanders and soldiers how to make more decisions in an ad hoc manner to meet the non-linear demands of 'informationalized' warfare encourages independent decision-making enough to enable adaptability in the field.[134] Rather, if this method of adaptation is fundamentally different than what small-unit [redacted] commanders (and their legacy commanders) are used to, it is unlikely those commanders will be as comfortable or skilled making such decisions during actual operations. Similar to negative regression (discussed in the section on acute stress, above) it is likely that during stressful situations commanders are likely to revert to to the patterns that are more familiar; in the case of the [redacted] that is to execute pre-existing operational plans rather than to adapt tactical and operational methods to changing situations.

[134] Kamphausen, Scobell, and Tanner, "The' People' in the PLA: Recruitment, Training, and Education in China's Military." pg 65.

	CHRNA4	BDNF	KIBRA	DBH	PRNP	HTR2A
Population frequency	**CHRNA4(T)** European: 58% Han: 23-25% Japanese: 35%	**BDNF (Met66)** European: 19% Han, Japanese, Korean: 38-49%	**KIBRA(T)** European: 27% Han: 78% Japanese:81%	**DBH(A)** European: 47% Han: 83-91% Japanese:84%	**PRNP(met)** European: 63-66% Han: 96-99% Japanese:98%	**TPH2(T)** European: 6% Han: 0.6%
Related cognitive functions	Distraction from false cues and no benefit from accurate cues	Diminished long term memory formation	• Increased episodic, working and long-term memory • Reduced cognitive flexibility	• Reduced automation bias • Reduced spatial working memory	• Better long-term memory • Increased risk of Alzheimer's and cognitive decline	• Better verbal memory
Theoretical effects on training	**Possible Western disadvantage** Less effective learning from cues embedded in simulated training systems or heads up displays	**Possible Western advantage** in retaining learned skills.	**Possible Eastern advantage** in speed of learning, and **disadvantage** when transferring knowledge to new weapons system or operational contexts	**Possible Eastern advantage** in knowing when to trust decision aids and **disadvantage** in spatial learning.	**Possible Eastern advantage** in retaining skills and **disadvantage** in terms of operational longevity	**Possible Western** advantage in retention of verbal teaching methods.
Behavioral Findings	Absent the contributions of cultural influences in language constructs, holistic processing, and context/object focus, there are no measureable differences between populations in long-term memory formation or general trainability.					

Genetic factors associated with memory, such as those outlined in the above table could affect learning speed and general trainability. Eastern populations have higher frequencies of some alleles associated with increased long-term memory retention and recall (KIBRA, PRNP) but lower frequencies of others (BDNF, DBH and TPH2). There are no measureable differences between populations in strict long-term memory tasks unless one begins to manipulate culturally influenced factors such as contextual or object-related information, indicating that the effects of these memory related genes either wash each other out across a population or fail to predict behavior with any reliability.

CHRNA4 and DBH interact with decision aids and teaching tools in laboratory settings and both indicate Eastern populations would benefit to a greater degree from decision-aids and cues embedded in training simulations than Western populations. This could translate into fewer simulation training hour unless training standards are define by time (200 flight hours for [redacted] fighter pilots, for instance), rather than performance in which case, subtle trust-related differences between operators and their training platforms are unlikely to have any real operational or cost related military implications.

Selection strategies. As much of the analysis in this report shows, genetic predisposition tells us less than we would like about performance capabilities and very little about complex behavior. Even so, the idea that genetic information can be used to match individuals to roles ideal to their talents is pervasive. Putting questions of predictive efficacy aside, the idea that genetics will pick one's career conflicts with the individualist sense of agency and meritocracy. As a result, any discussion of instituting a selection program based on genetic information meets resistance among operators and policy-makers alike. Current selection practices – such as [redacted] – may very well select for or against certain genetically-linked traits. There is inherent (and well-founded) skepticism that genetic predisposition cannot select for qualities such as 'heart' and 'drive'.

Given the difficulty we have seen in determining proficiency from genetic markers, it is tempting to let potential adversaries pursue unproductive methods for selection That said, members of collectivistic societies (that value doing one's duty for the in-group) may be more willing to fulfill roles for which they believe they are well suited for over those they may have greater interest in pursuing. Using genetic methodologies to guide selection in the militaries of interdependent societies may affect a kind of 'placebo-effect'; if one believes he is a good fit a position then he may inherently perform better in the role. Imposing the same methodologies to independent societies may well have the opposite effect in which, without a sense of agency and control over their role may be unmotivated and unproductive in the position.

TECHNICAL DEVELOPMENT & SYSTEM DESIGN

The adoption, development and design of military systems and technologies that enable those systems are also likely influenced by cultural and neurocognitive factors from their developers. Indeed, military culture influences how technologies are incorporated in concepts of operations. For instance, the US military uses communication technologies such as satellite computer displays of the areas of operations and other tools to push intelligence (and ISR products) directly to the front lines so that small unit commanders have better situational awareness and can make more informed decisions. The [redacted] on the other hand, has used communications technologies to increase centralized control of forward forces and to push decision-making higher up the chain of command.[135] "Informationization" strategies in the [redacted] ongoing modernization emphasizes "programming machines to supplement the weaknesses in human decision-making."[136] To this end the [redacted] emphasizes and invests heavily on redundant communication systems so that units will never have to operate without guidance from command even if an adversary attacks satellite systems, for instance.

Divergences in cognitive perspective may even go as far as to influence various stages in research from basic research attempts to solve common technical challenges, to final system design and operational use. Moreover, technologies that incorporate dynamic and reflexive brain-machine interfaces and human-integrated systems may inherently reflect cognitive styles of the user or even further polarize nascent cognitive biases buy responding to brain signals in different areas of the brain. The tendency of Eastern and Western students to represent math in spatial and language processing areas, respectively, would affect brain machine interfaces attempting to detect increased cognitive overload. A system built on Western patterns may then miss math-related increases in cognitive load if measures do not include spatial (parietal) brain regions.

MIGHT CULTURAL TENDENCIES BE REFLECTED IN SYSTEM DEVELOPMENT? Whether cultural tendencies shape how systems are designed is, by itself, difficult to answer because the predominant method of development involves absorbing technology designed by mainly Western militaries. There is, however, evidence of the influence of Western values and biases in both Western academic and defense-related technology development. Two examples include computer vision, and methods for aiding intelligence processing throughput and early threat detection.

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[135] Ironically, when decisions are considered political or sensitive, the US also leverages connectivity with forward units to exert centralized control over their actions. In some cases this involves questions of how to interpret rules of engagement. The most iconic example of this are images of the president and members of his staff and cabinet watching the raid on Osama bin Laden's compound in Abottabad in real-time from the White House.

[136] Kamphausen, Scobell, and Tanner, "The' People' in the PLA: Recruitment, Training, and Education in China's Military." pg 85.

The approaches and metrics for computer vision involve absolute, object-oriented and categorical themes, all of which are Western and individualist in nature. The aim of computer vision research and development is to create a machine capable of extracting meaningful information from a scene similar to how the human visual system. Far beyond gross characterization of contrast, luminance, and color (wavelength), true computer vision would also involve such capabilities as distinguishing foreground from background, interpreting motion, and dealing with missing information such as partly-obscured objects. Many algorithms approach this problem predominantly as one of object-recognition and attempt to identify edges and define contours outlining an object. See Figure 21 for an example from a lab in Berkley California; the algorithms the lab produced separates multiple overlapping objects from one another (child, bike and car) and then matches the objects against semantic database to categorize them. [137]

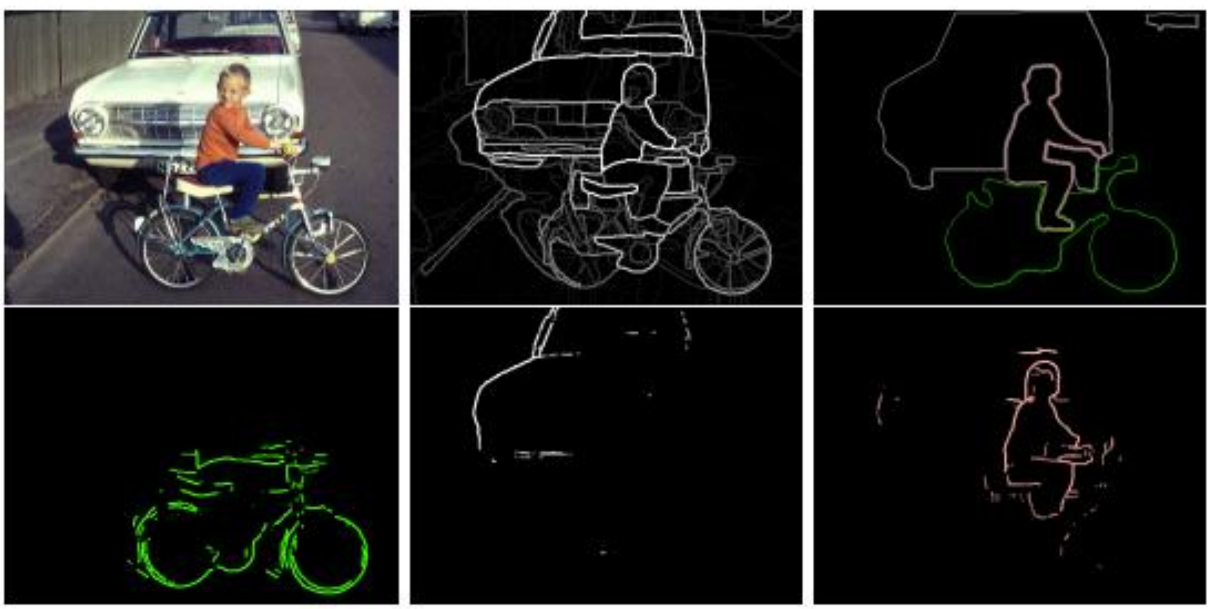

FIGURE 17: Object extraction and categorization algorithms from visual scenes from a laboratory in California.

Reviewing the research of a few Japanese labs, in contrast, reveals and emphasis on substance-related features such as texture characterization and reflective properties, and context-oriented challenges such as knitting together image mosaics to understand large scenes from multiple pictures (Computer Vision Laboratory at the University of Tokyo[138]), and place

[137] Bharath Hariharan et al., "Semantic Contours From Inverse Detectors," 2011, 991–98.
[138] http://www.cvl.iis.u-tokyo.ac.jp/photometry.html

recognition despite repetitive features and patterns (see Figure 22, from Okutomi & Tanaka Laboratory at the Tokyo Institute of Technology).[139] From a Western perspective, what is most striking about the scene analysis depicted in Figure 22 is that the algorithm ignores two iconic objects: the American flag and the Statue of Liberty.

Challenging this idea is the fact that Western laboratories have quite a few Eastern students and faculty. Though this is the case, the reverse is not true of Eastern laboratories (there are not as many Westerners in Eastern labs as there are Easterners in Western labs) meaning that even if Western labs reflect both viewpoints, that Eastern labs are likely to reflect a relatively greater "Eastern cognitive bias". Additionally, the Eastern students and scientists that travel to study and work in the West usually exhibit more Westernized perspectives than their Eastern peers[140] Finally, the majority of research dollars that fund Western labs come from Western sources, such as government institutions like the National Science Foundation and National Institutes of Health NIH, or from private companies like Google, which are also likely to be influenced by Westernized values, priorities, and motivations for technological development.

FIGURE 18: Computer vision research into scene and location recognition from the Tokyo Institute of Technology.

[139] http://www.ok.ctrl.titech.ac.jp/index.shtml
[140] Interview with Richard Nesbitt, July 2014

This evidence is anecdotal and ***a more systematic examination of Western and Eastern research trends is warranted to test the hypothesis that geographic and cultural neurocognitive differences may affect basic research approaches.***

Though a similar comparative study will likely not be possible in defense-related research and development, it is plausible that military systems also reflect neurocognitive dichotomies. DARPA's Cognitive Technology Threat Warning System (CT2WS), and the Rapid Serial Visual Presentation (RSVP) to aid Imagery intelligence (IMINT) analysis are both examples. CT2WS combines a digital imaging system with a brain monitoring system to direct the user's attention towards potential threats they may have seen visually but not registered consciously as he or she scans a scene. A Western approach to this sort of system would likely draw the user's attention towards objects, with little emphasis on context. Indeed, the system picks out object-related anomalies as potential threats. At the same time, because the system in part relies on how the brain responds to visual stimuli, it may be also that the system highlights whatever the user's brain has learned to deem important. RSVP works in a similar way, and uses pre-conscious brain signals to identify items of interest more rapidly than an unaided analyst would; RSVP would also be sensitive to what the user found salient, and hence would be subject to any cognitive tendencies inherent to the analyst. This might mean that an analyst that tends to de-emphasize contextual details might be more likely to over-interpret the significance of a military formation at an air show, for instance, as a hostile demonstration rather than as a spectacle for a summer fair. Increasing the speed of image throughput would exacerbate this tendency if it prevented more careful consideration of an entire image, for the sake of increasing processing speed. Here, increasing IMINT throughput may come at the cost of increasing the cultural polarization of the resulting intelligence products. It is unclear whether lower throughput or amplified cultural bias is worse for the quality of intelligence products, but may be worth considering how to overcome the

Innovation, or "re-innovation"?

In examples such as RSVP and CT2WS, the technologies – because they are dependent on the user's brain response – will reflect the cognitive tendencies of the user. In other case, such as in the algorithms developed for computer vision, the cognitive tendencies may be embedded in the system design. Differences in design may be seen only in systems that are 'home grown', and not on systems that are adapted and adopted once developed by others. The [redacted] approach to innovation focuses very little on basic research and to far greater extent on obtaining and adapting technologies developed by others for [redacted] use, a process known as 're-innovation'. The idea of 're-innovation' - or re-doing something novel – is inherently paradoxical in the Western view; an innovation cannot be repeated and still be innovative. Though absorbing external research and development is a common practice among 'catch up' nations that lack funding to support broad basic research engines, but the [redacted] in particular has institutionalized re-innovation. Tai Ming Cheung describes it as an active three-step process of recognizing (acquiring, by legitimate or illegitimate means), assimilating (reverse engineering) and utilizing (repurposing) knowledge and technology developed elsewhere.[141,142] In this case, we are more likely to observe the influence of neurocognitive differences in the ways the [redacted] operationalize technologies and systems, rather in native system design, per se.

SYSTEM-AIDED METHODS TO OVERCOME COGNITIVE MYOPIA?

In some of the above examples it would be advantageous to toggle back and forth between Eastern and Western cognitive styles to develop deeper perspectives on everything from tactical operations and intelligence analysis to developing novel computational solutions for technical challenges. If, in the case of intelligence analysis, we are aware of a relative blindness to contextual detail, we might be able to build systems to highlight features and relationships that might be otherwise overlooked. Not only might such analytical solutions help address common mirror-imaging problems, they may also help improve the efficacy of analyst/operator aids such as RSVP to improve throughput *and* quality rather than sacrificing the latter for the former.

[141] Tai Ming Cheung, *Forging China's Military Might*, (JHU Press, 2014).
[142] Tai Ming Cheung, "'Standing on the Shoulders of Past Pioneers': the Role of Foreign Technology Transfers in China's Defense Research, Development, and Acquisition Process," July 28, 2013, 1–42.

5. CONCLUSIONS

This study has examined a number of different culturally-divergent factors between Eastern and Western populations in order to better understand the potential military implications of how those factors affect neurocognitive processes. By examining these factors against performance disruptors (e.g., sleep deprivation, chronic, and acute stress) and within different military-relevant contexts (e.g., command & control, intelligence surveillance & reconnaissance, training and technological development) we have generated a series of hypotheses. For some, there is existing evidence against which we can test the ideas. For others such comparisons are still necessary and none should be adopted without further systematic investigation. The process however, has led to a number of important findings regarding how culture affects neurocognitive function and how defense institutions should approach related research in the future.

First, though we consider whether neurophysiological factors may be able to tell us something about population-wide tendencies and predispositions in behavior, epidemiological or historical evidence often contradicted what data from individuals would predict. This also means that on average, genetics are even less reliable predictors of population tendencies or of military advantage than individual behavior because there are a greater number of moderating and mediating factors (i.e., epigenetic and epistatic mechanisms) to shape or reverse the relationships between genetics, phenotype and group averages**.** The serotonin transporter variant (5-HTTP(s)) is instructive in this case; the variant is only linked to anxiety disorders in individualistic nations. We also considered other well-studied variations in dopaminergic alleles alike DAT1 and COMT as promising predictors of various executive functions (attention, working memory, stress reactivity). In each case however, other cultural factors ended up being far more predictive, such as features of each group's formal language structures. Even when considering large numbers, more often than not the predictions generated from genetic data did not hold up against behavioral and epidemiological findings. Similar to findings related to serotonin, a number of genes with divergent frequency distributions would have predicted Eastern populations would should have increased incidence of anxiety disorders or reactivity to threatening stimuli, yet Eastern cultures have both lower incidence of anxiety disorder and are less likely to show emotion that Western populations – exactly the reverse of what the genetic information alone would lead us to believe. This may be due to fact that most neuroscientific studies have been conducted in Western Educated Industrialized Rich Democratic (WEIRD) populations that often do not represent the majority of the globe's population.

But what of Chaio's Gene-culture Co-evolutionary Theory and the evidence that collectivism is linked to the serotonin transporter, and migratory behavior covaries with DRD4? The theory posits that cultures have selected for different traits based on their value structures and thus, have shaped the frequencies of related genetic alleles. Tabling critiques of the theory itself,[143] it still means that the most predictive factor is the culturally-bound value and construct (i.e., collectivism), not the gene.

This may be partly due to the lack of any tangible means to account for or quantify gene-gene (epistatic) and gene-environment (epigenetic) interactions on a large scale, but even if computing enables detailed modeling of complex adaptive systems with emergent properties, then the manner in which those models are built will likely be influenced by neurocognitive influences from cultural value systems and by a certain amount of randomness inherent to any system subject to environmental influence. The best method for understanding neurocognitive divergence is still to study behavior through traditional experimental, epidemiological, and historical processes.

Second, when we observe behavioral differences in the lab between cultures, we must be careful to consider how those behaviors may change beyond the lab. The initial studies on risk-taking behavior, for instance, suggested that Eastern populations tend to be riskier than Westerners. Those studies, however, used monetary incentives and gambling as a means to assess risk without considering that each culture places different value on monetary (as opposed to social) assets which may not be as important in interdependent cultures. If risk-taking behavior is domain-specific, then we must also consider that that findings from social and monetary experiments will not apply to defense-related activities. Moreover, as historical examples have demonstrated, these intra-domain decisions tell us little about inter-domain decisions, or how a nation balances the relative risks between domains to guide a decision such as whether to initiate a border dispute with more powerful Soviet forces. The most value then we can derive from experimental studies is to better understand the nature of cultural differences we observe in the world, which brings us to our last point.

Finally, when we consider the ways in which culture shapes the brain and its function, it is important to understand how neural computations are and are not affected. David Marr's levels of analysis provide a helpful framework in this regard. Marr's three levels include 1) **the computational level, goal** or problem the computation is trying to solve; 2) **the representation (inputs/outputs) and algorithm** or strategy employed to solve the problem; and 3) t**he physical implementation** or hardware responsible for executing the algorithm. Culture affects level 1 by

[143] Critics of Gene Culture Co-evolutionary Theory do not believe that timelines required to shape genetic frequencies within a population are too long to for cultural preferences to have shaped the distributions in any substantive way. They attribute the differences to geographic genetic drift. Whether the more individualistic in a population were

setting priorities and goals according to culturally-determined value structures. What is the problem one is trying to solve? Culture can also affect level 2, just as language and numerical systems affect whether one represents numbers in their spatial or language processing regions. Culture has the least influence over level 3, the physical implementation of the machine that executes the computation.

Marr's levels are useful beyond the world of computational neuroscience and may help guide strategic military thinking in a way that naturally integrates cultural motivations into the military computation. Strategists most often consider levels 2 and 3, which correspond to a military's concepts of operations, and what weapons, systems and mechanisms of influence each side can use to reach their goal, respectively. Level 1, however, is often assumed without careful consideration. If we begin by thinking about what problem each military is trying to solve, we may consider factors beyond stated military goals (regain lands lost in an earlier border dispute) with goals in the context of cultural motivations (regain 'face' or respect from losing land in border dispute) or how neurocognitive differences may affect the interpretation of outcomes and goals in the first place. Such analysis may help us better understand not only what outcomes are and are not acceptable to each side, but also how such goals may shape concepts of operations (level 2) and investments into assets of influence (level 3).

Throughout the report we have seen ways culture and environment affect how information is perceived, conceptualized and used. Worldwide patterns indicate that North Western individualism is the outlier in this regard and that much of what we think we know about neurocognitive function applies to a sample that does not represent the majority of the world's populace. If our aim is to better understand our worldwide counterparts, we must conduct research that spans not only populations but also disciplines including the neuroscientific, anthropological, epidemiological, and historical.

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