Socio-Technical Effects of Artificial Intelligence Systems Within the Navy

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

As the world moves further into the 21st century, the amount of data that is collected and stored continues to grow exponentially. According to IBM, 90 percent of the data we possess today comes from the last 2 years alone, and Dell EMC estimates that we will obtain around 40 trillion gigabytes of data by the end of this year (Petrov, 2020). This vast collection holds insights to problems that companies, institutions, and governments face, but these insights are often hidden deep within the mess of confusion and uselessness that make up the majority of collected data. Over the past few years, advances in artificial intelligence (AI) allow it to successfully sort through the mess and find useful trends from which humans generate decisions. Today a technological race takes place on all fronts to see who will develop new systems that provide an advantage over their competitors, including those in the geo-political realm (Meers, 2020).

This artificial intelligence “arms race” carries large-scale ramifications in the military strength of nations and their ability to project power across the globe. Today the United States directs large amounts of funding to the research and development of automation and AI within the military in an effort to stay ahead of near-peer competitors like Russia and China, who both express their belief that these technologies will play a huge role in deciding the major world powers in the coming decades (Heller, 2019a). The ability of the United States military to remain the dominant fighting force in the world is imperative not only for the defense of its people against foreign attacks, but as a powerful diplomatic tool that supports the nation’s foreign policy interests; artificial intelligence, which builds upon advances in automation, has the power to ensure these needs.

A challenge that comes with the development of automation and AI is the inarguable fact that the implementation of this technology will bring about large-scale changes in many areas of the Navy, including warfighting strategy and tactics, training, intelligence, and logistics. Automation, an important stepping stone in the process of AI development, has already significantly changed the way the Navy operates. The developers of the technology and the leaders who are tasked with deciding where to use it may not foresee many of these changes, some of which could result in significant consequences.

This research will discern how automated technologies can be safely, ethically, and successfully integrated into Naval operations.

Interactive Socio-Technical Aspects of Artificial Intelligence Adoption in the Navy

Artificial intelligence will certainly change the way the United States Navy operates in a myriad of ways, but viewing it as strictly a stand-alone technology which functions fully autonomously will cause more harm than good. Just like most technology, the effectiveness of AI depends on the users who operate it; and due to the idea that it may one day replace those users and act as an independent actor in its own right, the need to understand the underlying socio-technical issues becomes all the more important. To understand this technology, one must begin to focus on the potential for unintended consequences. Looking at the development of AI under the lens of a socio-technical framework possibly leads to more thoughtful and successful application.

Before looking at the socio-technical specifics of automation and AI and their implementation within the military, I will introduce the Interactive Socio-Technical Analysis (ISTA) framework and its focus on unintended consequences. This framework argues that unintended consequences of technology come from interactions between the technology-in-use, the organizational culture and workflows, and the developers of future iterations who study past applications and decide what to improve (Harrison, Koppel, and Bar-Lev, 2007). ISTA focuses on five main interactions, the first of which exists between new technologies and the current social practices of the organization. As organizations introduce new technologies, these technologies affect the way users interact with each other.

The second interaction focuses on how the existing technical & physical infrastructures mediate the use of new technologies. When designers introduce a new technology, they need to find a way to find a way to fit it in with the current system that provides a significant improvement, while minimizing the need for a sharp learning curve. When people forget or ignore this interaction, thoughtless implementation leads to disastrous consequences when the new and existing technologies do not integrate well.

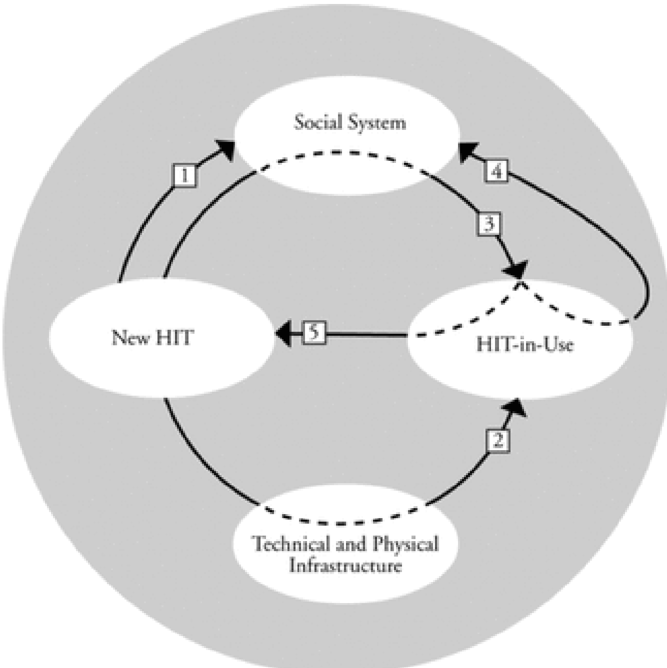

Figure 1. Illustration of the Interactive Socio-Technical Analysis Framework (Bar-Lev, Harrison, and Koppel, 2007). HIT (healthcare information technology) in this figure represents the new technology.

The third interaction states that just as new technologies change the culture of an organization, established practices within the organization also end up altering the use of those new technologies. Users tend to find new ways of using the tools available to them, sometimes in ways the designers do not expect (Bar-Lev, Harrison, and Koppel, 2007). The fourth interaction touches upon how the specific use of new technologies by an organization will in turn affect its culture. An organization's use of new technology changes the way an organization views itself and what it values, or in some cases goes so far as to drive changes in policy for proper procedure.

The fifth and final interaction shows how the use of new technologies within the culture and existing technical and physical infrastructures lead to thoughtful redesign that takes into account the lessons learned from prior iterations. This final interaction ties together the point at which technology moves from novel to established, and the beginning of the process for the next round of innovations that will likely shake up the system yet again, emphasizing that technology design builds upon itself over numerous cycles. Upstanding designers look to past introductions of technology to get a sense of how future applications will alter both the current system and the culture of the users surrounding it.

For the Navy to successfully develop and adopt artificial intelligence technologies that deal with the incredible amount of data that it has at its fingertips, it needs to understand and respect the socio-technical aspects of system design. This starts with understanding the interactions between new technologies and the technical, physical, and cultural domains in which they exist. Developing a clear and holistic AI blueprint needs to happen for successful systems to exist, and designers need to realize the effect this technology will bear on the technology, culture, and on individual sailors and Marines in the fleet.

Future Artificial Intelligence Systems of the Navy

The United States Department of Defense (DoD) views artificial intelligence as a technology that can provide benefits to numerous aspects of the military, from logistics to intelligence to autonomous vehicles and more. The DoD budget proposal from early this year, which increased the money set aside for AI from $780 million in 2020 to 841 million in 2021, reflects this sentiment. It also calls for the development of a new department called the Joint Artificial Intelligence Center (JAIC), which will focus on the development and testing of automation across all branches (Heckman, 2020).

There are numerous arguments about what the future of the military will look like with these new systems. Some people like to picture a fully unmanned force that functions almost completely on its own, but AI will probably act more as a tool to supplement human cognition and decision making, at least in the near-future. While it excels at making rule-based decisions and predicting outcomes for situations it has been trained on, it struggles when dealing with contextual decisions, emotional factors, and situations outside of its training set (Arquilla and Denning, 2019). Due intrinsically dynamic, unpredictable, and at times emotional nature of warfare, using AI within the battlespace as a stand-alone technology may not work. The creation of man-in-the-loop and man-on-the-loop programs could allow commanders to utilize the benefits that AI brings, while still maintaining full command and control of the battlespace (Hampshire, 2019).

One argument for the importance of developing the Navy's artificial intelligence technology now focuses on the importance of building a foundation that will support future technologies. The technical part of this argument focuses on building a vast database today that will train the autonomous software of tomorrow. As mentioned above, AI does not work well when faced with situations outside of the data it was trained on. Compiling as much data as possible so that the algorithm has more information on potential scenarios and makes predictions with greater confidence may help mitigate this issue (Heller 2019a). Two issues come up with this solution: in an environment as complex as warfare, the ability to gather data on all possible conditions is impossible, and data collection often times costs lots of money. While we may one day possess a forward-deployed Navy that effectively utilizes AI across different tactical components, the likely use of this technology today centers around strategic elements such as intelligence, logistics, administration, and more.

One of the keys to unlocking the power of artificial intelligence, both in today's systems and those developed for tomorrow, is the use of automation. Automation, though sometimes used as a synonym to artificial intelligence, has a much lower level of complexity. As the name suggests, automation performs tasks automatically and without human intervention. It will do exactly as its program reads, and will not change based on the outcomes of the process. Artificial intelligence takes automation a step further by performing tasks without human intervention, but it has the ability to "learn" by looking for patterns, comparing observed and expected outcomes, and work outside of what the programmer initially intended. Automation will play one very important role – continuously collecting and compiling information from the environment – while AI will analyze the information and make determinations based on what it "sees," allowing human users to focus on oversight, validation, and making the final decision (Hankiewicz, 2018). Unfortunately, incidents over the last few years highlight the failure of the Navy to safely and effectively implement automation.

In 2017, the United States Navy tragically lost seventeen sailors in two separate accidents. The first, involving the USS Fitzgerald, occurred when the warship ran into the MV ACX Crystal off the coast of Japan. While many factors played a role in this tragic incident, the ineffectiveness of the automated radar systems and inability of the Navy to remedy known problems in the computers helped bring about the end result (NTSB, 2017 a). A few months later, the USS John S. McCain ran into the Alnic MC after installing touchscreens on the ship's steering and propulsion consoles. The sailors who operated these consoles did not adequately understand how to properly use them due to poor design and implementation, and ended up making a series of costly mistakes that led to the death of ten of their shipmates (NTSB, 2017 b). These incidents differ in a few key ways: one shows the Navy's inability to update and maintain older automated technology — the other its struggle to implement new components that introduce new automation, and increase the amount of available manpower resources. For the Navy to properly utilize the insights of artificial intelligence, they need to learn how to use their automated systems in a safe manner.

Research Question and Methods

How has the design of automation within the military led to unintended consequences, and how have those consequences led to changes in future technologies? The Navy's ability to create and use these technologies will directly affect their ability to compete with near-peer adversaries in the coming years.

The research for this paper comes from two separate case studies. The report compiled by the National Transportation Safety Board provides detailed information on the first case study, an incident between the USS John S. McCain and the Alnic MC, along with the determined reasons for the collision and the recommended steps taken to avoid an event in the future. Media accounts from Pro Publica and the United States Naval Institute help give more contextual information on the event. The second case study, while not one that focuses on the Navy, still helps analyze the ways unintended consequences can play out with automation in a warfare environment by detailing the fratricide incidents between a patriot missile system, and US and coalition aircraft. Information on this comes from a report done by the Defense Science Board, and writing from the Center for a New American Security on an account of the Army's reaction to the unfortunate occasions. Analysis on these case studies used the Interactive Socio-Technical (ISTA) framework to highlight the ways shortcomings in design can lead to issues not predicted by the design team. There are certainly examples of automation and artificial intelligence that work well in the Navy (the AEGIS fire control system comes to mind) and across the other branches of service, but I will not discuss them in depth. Instead, I aim to shed light on some of the hurdles the military has already run into in an effort to prevent future mistakes that might slow the advancement of these technologies.

Analyzing Case Studies on the Shortcomings of Automation Using ISTA

These case studies show that poor use of automation in the military comes from military leaders not fully understanding the automated apparatus given to them, and this in turn leads to poor adoption of that technology when put in the hand of the actual users. In the end, the iterative cycle continues to build upon the lessons learned from the way the users embrace and work with the new system, but hopefully this can happen without the need for accidents that require the armed forces to learn the hard way. Designers need to work more closely with both military leaders and users so that everyone is on the same page and collectively holds a similar idea of what the technology should do.

Patriot's Full Automation Setting Changes the Way the Army Views "Lethal Autonomy"

In the 1990's, the Patriot missile system saw its first action in Iraq during Operation Desert Storm. Using surface to air missiles, it was designed to defend against enemy tactical ballistic missiles, cruise missiles, and aircraft. At its inception, the weapon had a fully automatic mode from a previous missile system called Safeguard, meaning it could find and engage targets without any input from a human operator, but tactical usage guidance said that it should be employed in a way where the operators had to give approval before the Patriot would fire at a target. During Desert Storm, the operators ended up using the automated configuration, which worked sufficiently enough for mission commanders to start seeing automated defense as a viable strategy when using Patriot. A report stated, "Self-congratulation led to complacency, which led to complacency, which led to unwarranted trust in, and reliance on, the system's automatic operating mode" (Hawley, 2017). After using the new technology, the culture of the Army changed to one that did not view the user as such a necessary part of that sequence. The designers, while understanding that their system had the capability to work automatically, did not see how taking patriot missile operator out of the equation and giving him or her less active control lead to decreased situational awareness and complacency.

Problems with Both the Patriot's Automated Program and Its Physical Environment

Ballistic missile defense (BMD) often involves looking at a low number of contacts high in the air, and determining the possibility that those contacts are hostile ballistic missiles. Integrated air and missile defense (IAMD), on the other hand, deals the aerial environment lower down, where the number of contacts that an automated system has to find and track are much higher. The automated capabilities of the Patriot came from an old BMD weapon, and using that software in IAMD was a novel concept. This ended up causing problems, as the automation designed for BMD was not suitable for defending against conventional air targets. In fact, the Patriot engaged 9 enemies while dealing with 41,000 friendly aircraft, coming to a little over 4,500 friendly targets for every enemy target (Hawley, 2017). Compounded on top of this was the lack of situational awareness due to an inability to share data among the existing systems. It did not yet have the ability to share its battlefield picture with other systems like the Navy's Aegis Missile Defense System or Airborne Early Warning and Control System (AWACS) used by US military aircraft. The Defense Science Board stated, "The Task Force believes that we are a long way from that vision. The communication links, the ability to correlate target tracks by disparate sensors, and the overall information architecture are simply not there" (DSB, 2005). The Patriot not only had a poorly applied automation system not designed for the physical space in which it deployed, but it could not effectively work with the established defense systems around it. These factors ended up negatively mediating its use, and contributed to its eventual fratricide attacks.

Sailors' Lack of Trust in the Ship's Controls Causes Chaos

On August 21, 2017, the USS John McCain and the Alnic MC collided after the McCain's sailors struggled to use the ship's steering system correctly. The Integrated Bridge and Navigation System (IBNS) was a new steering console only a few years old that aimed to reduce the number of sailors required on the bridge of a ship at a given time. Unfortunately, most of the crew who used the consoles had little understanding of how they worked, and were confused by a lot of the features. In the month leading up to the crash, the ship logged around sixty major steering faults, and the captain of the McCain often ordered the IBNS to run in backup mode to get rid of some of the confusing features, though this left the ship vulnerable to other problems (Miller, Rose, Faturechi, and Chang, 2019). On the day of the incident, the complexity of the ship's surroundings caused the captain to split the steering duties between two stations, the helm and the lee helm. Due to the backup configuration of the steering console, the transfer was improperly done, eventually leading to a loss of control and the collision with the Alnic. The report from the National Transportation Safety Board (NTSB) concluded that since the crew had the steering in backup mode, any IBNS station could take complete control of the ship's steering from the helmsman—who normally had control—without notifying the helmsman's station. Furthermore, a lack of "tactile feedback" to the mismatch of the throttles increased the likelihood of operator error—a big reason for why the McCain suffered a loss of control (NTSB, 2019). In this situation, the culture of the ship, lacking confidence in the automated features of their ship's steering, decided to use the technology in a way those who build it did not expect by placing it in backup mode and therefore removing a lot of the built-in safety features. The wary attitude toward the IBNS extended further than just the crew of the McCain, as other ships preferred to use the backup mode too (Miller, Rose, Faturechi, and Chang, 2019). The designers created a new technology that differed too much from the old ways and was too complex for established ship captains and young enlisted operators alike. It did not fit with the operational culture, and was therefore used in unanticipated ways.

Responses from the Army and Navy

Interaction four states that the use of a new technology will eventually change the social system. Although originating from tragic events, the changes that the Army and Navy made ended up improving their culture and found out ways to better utilize their imperfect systems. The Army ended up changing the "kill chain" to provide more user oversight on engagement decisions, and altered training to encourage operators to check the system and validate the automated tracking and classification results more often (DSB, 2005). In the case of the USS John McCain, the Navy also improved training for IBNS users and consolidated responsibility and authority for the consoles, so that a single person was always in charge of overseeing its use and had enough understanding to diagnose any errors that might slip by the operators (NTSB, 2019). For the Army, the culture went from believing their missile system was an immaculate example of automation in warfare to understanding and accounting for its underlying weaknesses. For the Navy, they now saw their dangerously flawed consoles as something they could at least manage. In both cases, the initial problem stemmed from a dearth of knowledge that led each organization to develop inaccurate ideas of what their systems could do. Eventually organizations will understand and adapt technology to their specifications, but that technology should cater to the culture of the organization as much as possible, so the intended use and the eventual use align as closely as possible.

The Navy's Next Round of Innovation Learns from What Came Before

The ISTA framework talks about the advancement of technology as an iterative process, and one can see that clearly in the case of the Navy's IBNS consoles. The next update to the consoles will go back to physical steering systems with simplified touch screens, hoping to keep sailors comfortable with familiar controls while adding some modern features as well. Addressing the recommendations for a future system, Rear Admiral Bill Galinis stated "we got away from physical throttles, and that was probably the number-one feedback from the fleet – they said, just give us throttles we can use" (Eckstein, 2019). From the Navy's experiences in using the IBNS came the beginning of another design process to create a better system, one that will hopefully work better in the environment for which it is intended.

Summary of Findings

After analyzing the two case studies, the interactions discussed in the ISTA framework point out the issues involved in developing autonomous systems for the military. Often times, a misunderstanding of what automation can do ends up leading to unintended consequences. The military culture also plays a role in the mistakes made surrounding these technologies. Often times those making the strategic or organizational decisions have an idea of how to best utilize the system, but those ideas fail to work effectively when placed in the hands of the actual users. In the end, designers need to work more closely with the users and see how they function when operating the mechanics in accordance with their intended use.

Discussion

When determining how to best go about answering the question of how the Navy has struggled to implement automation, the ISTA framework offers a way to focus on contrasting the intended use of innovation with its actual use. In the Navy, and in the military as a whole, the new software and mechanics come from private contractors, some of whom may not have much contact with the service members who will end up using their technology. This lack of communication between the creators and the operators stood out as a possible reason for some of the military's incidents using automated technology, especially since automation and artificial intelligence are still somewhat misunderstood by the general public. ISTA also focuses on how the culture of an organization comes into play. For the Navy, whose culture has a profound impact on how the organization operates, this framework felt like an excellent way to see just how much the culture played a role in adoption of automated technology.

The Navy tends to use its own mistakes as case studies to prevent similar events from happening in the future. The cases often look at the human factors that play into a situation such as leadership choices, ethical considerations, and stress/emotional factors. Using the ISTA framework adds another dimension to the human side of these events by analyzing how the relationship between users and technology, or how the technology itself may play a role in bringing about the outcomes of a case.

This paper talks about the shortcomings of automated technologies in the military, but I also want to bring up some possible solutions, and for that I turn to the AI building blocks developed by the United Kingdom's Defense Science and Technology Laboratory. In their framework, they provide nine different components, split among three different categories, that all make up successful development of AI technology. I will not go into much detail on it, other than to say that a lot of the factors which led to the unintended consequences in the case studies analyzed in this paper are covered in the building blocks; examples include a focus on integration, platforms, confidence, and interaction (DSTL, 2020). Thinking more about integration and platforms will allow new technology to mesh well with the existing system, and confidence and interaction allows the culture to feel comfortable with the technology and with the way it changes how users connect with each other.

Like most research, there are some limitations. This paper highlighted examples of negative unintended consequences, and did little to bring to light examples of positive unintended consequences. This was mainly because bad incidents often receive a great deal of publicity, while successful use is taken as the norm and therefore does not get as much attention. The ISTA framework also seems to work best when analyzing negative unintended consequences. In the paper where the authors introduce the framework, the examples they use involve poor results of implementing health information technology within a hospital. One reason for this is that, again, people may care more about how things fail so they avoid doing something similar in the future.

The case studies used in this paper concentrate on automation, while a lot of the technical section focuses on artificial intelligence. This is mainly because the Navy has little to no artificially intelligent systems to analyze, which is another limitation of this research. Automation, however, creates the foundation for artificial intelligence, so the Navy needs to first figure out automation before they can move to AI. Similar to how the Wright brother's first plane led to the world of aviation and all the subsequent benefits over the years, automation will act as a stepping stone for AI and allow the Navy to perform at a smarter, faster, and cheaper level.

Conclusion

The Navy acts as more than just a weapon of war. It represents American ideals and protects American interests abroad. Consequently, the Navy ceaselessly designs and tests new technologies which allow it to maintain its status as one of the premier global fighting forces in the world, but that innovation must be thoughtful, safe, and it must genuinely bring about some improvement in the Navy's warfighting abilities. Automation and artificial intelligence have a lot of potential when it comes to ushering in a new age of twenty-first century naval warfare, but the only way to successfully make it there is to focus on design that fits in with the organizational environment and makes positive contributions when put in the hands of the sailors and marines who will use it.

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