



Beyond Super Soldiers and Battle Suits

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Science fiction is always fascinating to follow, because at least some of the ideas presented in the genre do become reality over time. The concept of "super soldiers" is a case in point. Although the protagonists in Marvel's iconic Avengers comic books (and now movies) are still a long way from being realistic, we are unquestionably trending in that direction. Thus, the character of Captain America is a soldier enhanced by the government using a special serum to make him stronger, faster and more resilient, while Iron Man is an operator encased in full body armor that affords him super human strength, advanced weapons, and extrasensory systems. Even though such enhancements are still a stretch, performance drugs, exoskeletons, and other new technologies are increasingly augmenting - and expanding - the capabilities of today's warfighters.

The concept of human enhancement for military applications dates back more than two centuries. During the American Revolutionary war, doctors used vaccinations to enhance the immune systems of soldiers against smallpox in an effort to make fighting forces more resilient.[1] Fast forward to the present day, and the U.S. military is developing strategies to help make humans better through "combined collaborative human-machine battle networks" that use artificial intelligence to speed human decision-making, through wearable electronics, or via "human-machine combat teaming with unmanned systems" such as controlling drones using only the mind.[2] Other methods to enhance humans in the near term include drugs, meditation, and electrical stimulation of the brain. And in the long term, whether we like it or not, genetics may play a role in developing humans for military applications.

Looking ahead, all of these enhancement options - along with their myriad ethical implications - must be considered, both in order to optimize the U.S. military and so we can defend against similar advances that are now being explored by our adversaries.

ENHANCEMENTS THROUGH EXOSKELETONS

The Iron Man suit shown in the movies regularly defies the laws of physics, but the concept of exoskeletons and technologically advanced full body armor has been under development by the U.S. military and its defense contractors, as well as by potential adversaries of the United States, for some time now. There are several exoskeleton projects funded by the Department of Defense (DoD) that have already demonstrated significant potential.

One such effort is a system dubbed "Air Legs." Funded by the Defense Advanced Research Project Agency (DARPA) and developed by Arizona State University, the system consists of a leg-based exoskeleton with air cylinders that move rapidly, allowing test subjects to run approximately 12 miles per hour.[3] "Air Legs," moreover, is not alone. The Lockheed-Martin Corporation has designed another leg-based exoskeleton, known as the FORTIS Knee-Stress Relief Device (K-SRD), which incorporates artificial intelligence and actuators that understand human movement, allowing users to significantly increase the amount of weight a user can lift. A subject typically capable of squat lifting 185 lbs. for a total of 20-25 repetitions can double the amount of repetitions while wearing an K-SRD unit.[4]

In addition to leg-based exoskeletons, contractors have made major strides in development of full body suits. Raytheon has constructed the XOS2 robotic suit, which allows users to remain nimble while capable of lifting 200 lbs. and punching through walls (although the suit still needs to be tethered to a power supply, which represents a major impediment).[5] Arguably the most advanced full suit program is the Tactical Assault Light Operator Suit (TALOS) program. Researchers from the Special Operations Command and the Army have teamed to develop a TALOS capable of breaking into a building, enduring heavy enemy fire, and remaining in a combat zone for long periods of time.[6]

Despite the potential military applications for exoskeletons and full body robotic suits, the advantages must be weighed against existing shortcomings. Noncombat military applications and soldiers recovering from injury may stand the most to benefit from some of these technologies, particularly the leg-based exoskeletons. For combat missions, while formidable, robotic suits have serious limitations currently due to power constraints. Moreover, even when longer lasting battery options become available, it may still be more practical to have a semi- or fully autonomous robot carry out the mission.[7] However, at least in the immediate near term, further development of the helmets in robotic suits and those already worn by aviators holds definite potential for increased situational awareness through better digital displays that overlay information about the surrounding environment in real-time.[8]

AUGMENTATION THROUGH HUMAN MACHINE INTERFACES

Headsets and other brain computer interfaces (BCI) are an area of human enhancement that is being employed in the civilian sector, particularly by elite athletes, to assist in attaining peak performance. Through a process called transcranial direct-current stimulation (tDCS), a device transmits a small amount of electricity across the skull to specific areas of the brain, which may allow the organ to enter "a state of hyper-elasticity, allowing users to learn better and more efficiently." [9] Some headsets used for tDCS look nearly identical to a set of Beats brand over-the-ear headphones.

Applications of tDCS are already gaining prevalence, and the results are noteworthy. Athletes are able to train longer at high levels and develop more power and explosiveness in their movements - attributes which would work well for soldiers in the context of national security.[10] DARPA has funded these types of electrical stimulation technologies to enhance the ability to "speak foreign languages, [as well as for] analyzing surveillance images, and marksmanship." [11] Impressively, U.S. Air Force studies have showing elongated performance times for tasks carried out through tDCS, with no measurable side effects.[12] The tDCS devices developed to date have been external, but there is also the possibility of placing small devices inside the brain to specifically target and amplify certain brain functions through electric stimulation.[13]

Brain machine interfaces can also be used for more involved applications. James Cameron's box office hit *Avatar* showcased the idea of connecting a human brain to a machine that remotely controls a genetically engineered body in real-time. The concept of using a human brain to remotely control something, a procedure known as telepresence, is not too far fetched. Indeed, humans will likely be able to control drones with their minds.[14] The U.S. Army has worked with researchers from Arizona State University to fund technology "that lets a human control multiple drones using their brain waves, and the group is now working on squadrons of drones that could perform complex operations," which they estimate could be ready in 5-10 years.[15]

Another nascent but potentially game changing application of BCI technology is improved communications. DARPA has committed funding to a project called Silent Talk, which allows soldiers in combat zones to communicate seemingly telepathically, by "allow[ing] user-to-user communication on the battlefield without the use of vocalized speech through analysis of neural signals." [16] The technology is far from mature, but could pay major dividends if allowed to develop. Even further down the line, it may become possible to have memory storage devices implanted in the brain that allow for the ability to transfer information as a download for instant information sharing with another person (similar to the title character's abilities in the 1995 Keanu Reeves movie *Johnny Mnemonic*).[17]

Technology interfacing with other parts of the body, especially through sensor systems, is also under development to enhance humans. The Army Research Laboratory (ARL) has launched a Human Variability Project that outfits soldiers with sensors throughout their bodies designed to measure "biophysical data" - essentially cataloging everything that occurs in the body, as well as its interactions with the environment, down to the genetic level in machine-readable signals aimed at helping improve individual performance.[18] This and other large human variability data collection programs, in turn, may be able to help dictate which individuals are best suited for specific jobs, missions, or to use specific weapons.[19]

BIOLOGICAL ENHANCEMENT AND DEGRADATION

While exoskeletons and neural interfaces showcase important human enhancing possibilities, some of the more readily available performance aids can also provide U.S. soldiers with significant gains. According to human enhancement specialist Andrew Herr, "When properly applied, performance nutrition, supplements, legal stimulants such as caffeine, and meditation can provide huge benefits to focus, attention, and performance when sleep deprived."

Brain stimulants in particular are ubiquitous in civilian life, with many students using Ritalin or Modafinil to increase their scholastic performance.[21] In the military, pilots have historically relied on prescription dextroamphetamine, colloquially known as "Go Pills," to maintain alertness on long missions, despite known side effects that include "confusion, delusions, auditory hallucinations, aggression and, in extreme cases, psychotic behavior." [22] More recently, the U.S. Air Force has switched to modafinil, a newer generation prescription drug used by doctors to treat narcolepsy but which has cognitive benefits for healthy, sleep-deprived individuals. Large segments of the U.S. Army are likewise known to rely on supplements for self-enhancement. Unfortunately, the military does not currently provide guidance on which supplements to use, so the vast majority of the substances soldiers take are ineffective or could actually have adverse effects.[23]

Just as it is possible to build people up with drugs, it is also possible to degrade humans using bioweapons or even neuroweapons by "modify[ing] opponents' thoughts, feelings, senses, actions, health or - in some cases - to incur lethal consequences." [24] A specific application could be to target an adversarial "political or military leader to evoke a change in his or her ideas, emotions and behavior. This could exert effects on those they lead, influencing their views and actions toward either conformity or dissonance." [25]

At the cellular level, there have been interesting developments for enhancement. Researchers on multiple continents have prototyped ways to create artificial or "smart" blood that can increase the amount of oxygen carried in the bloodstream, allowing athletes or soldiers increased energy.[26] There is also future potential for programmable "synthetic white blood cells that could receive software updates" to fight diseases or infections.[27] And, while not yet ready for remote control, the newest generation of cancer treatments already is using genetically engineered white blood cells tailored to attack specific targets.

Enhancement at the genetic level is where the technology for military applications becomes both impressive and potentially frightening. There have been significant strides made over the past two decades in understanding the human genome, and as a result there now exists the potential to better plot where someone's optimal career trajectory should lead. Although not currently employed by the military, it is now possible to use genetic variants to determine a range of performance-relevant factors. For example, some genetic variants predispose an individual to have difficulty learning tonal languages, such as Chinese. However, this would not be a problem if the same individual were to learn Russian. These same variants also can suggest the probability of cognitive decline, or indicate the type of physical activity for which an individual is best suited.[28] This technique could reduce costs for the military and lead to a more effective fighting force. Yet, although the military regularly relies on aptitude tests to disqualify or qualify candidates for special operations, there is still extreme hesitancy toward the use of biotechnology for such assessments.

Gene modification is the likely future that we will live in, thanks to CRISPR-Cas9, "a new gene editing technology that offers the potential for substantial improvement over other gene editing technologies in ease of use, speed, efficacy, and cost." [29] Using CRISPR, researchers in China have already conducted trials on embryos to correct for blood disorders, sparking a major backlash from the scientific community.[30] Engineering embryos to receive desirable traits has the potential to be abused, and could truly lead to the creation of super soldiers. And while there is worldwide caution relating to the technology, due to its ethical and moral implications, there is ultimately no way to limit its spread, given its accessibility.[31]

ARE U.S. ADVERSARIES ENHANCING HUMANS FOR WAR?

Former U.S. Deputy Secretary of Defense Bob Work has made it clear that our adversaries "are pursuing enhanced human operations, and [that] it scares the crap out of us." [32] He has also stated that "[a]ltering human beings from the inside to more effectively fight in combat presents ethical dilemmas for American scientists and military planners." [33] Indeed, the U.S. may never want to pursue some types of human enhancement. But it nevertheless must be prepared to deal with adversaries who have no similar compunctions about moving ahead in this realm.

Russia is a case in point. One need look no further than the country's civilian sector to see how lax the Russian government truly is about human enhancement initiatives. The use of performance-enhancing drugs by Russian Olympic athletes before and during the 2012 Games was well-known, state sanctioned and institutionally abetted by the Russian government. [34] The implications are ominous; concrete evidence of human enhancement in the Russian military is not readily available, but if the Kremlin is covertly providing performance-enhancing drugs to the country's athletes it is reasonable to conclude that it is doing far more for its warfighters.

There is more overt evidence of human enhancement in China. Genetic enhancements are known to have been conducted on dogs and, as mentioned above, Chinese scientists have already experimented with gene editing on human embryos for health applications. Reportedly in their efforts to combat human diseases including Parkinson's and muscular dystrophy, researchers in China have successfully suppressed the myostatin gene, which regulates muscle growth in both dogs and humans. In experiments with the embryos of two beagles, the dogs were born with significantly increased muscle mass. [35]

As a thought experiment, imagine that an adversary finds a way to engineer soldiers with increased cognitive abilities that provide them with a material advantage on the battlefield. If the U.S. were to ignore such developments, by the time this new generation of soldiers demonstrated its true prowess as adults, we could find ourselves two decades behind the development curve. [36]

PREPARING FOR AN ENHANCED FUTURE

The potential for human enhancement is immeasurable. However, ethical considerations will need to be weighed when the U.S. military evaluates which forms of enhancements to pursue. The Department of Defense has demonstrated a propensity to fund research that enhances humans through exoskeletons and human machine interfaces, and it should continue to fund such worthy initiatives. However, the hesitancy now visible within the U.S. military to pursue some of the more low-tech forms of biological human enhancements is less advisable. A concerted effort should be made to pursue research on subjects such as performance-enhancing drugs, cognitive enhancements and bio-technology that hold the potential to increase the operational effectiveness of the military.

As for genetic modification, the U.S. military has wisely steered clear of eugenics to date. However, some of America's adversaries might not prove to be so scrupulous. As a result, the U.S. military needs to begin planning now to counter such initiatives. If it does not, we may wake up two decades hence wholly unprepared for the battlefield of the future.

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