Studia Humana
Volume 11:1 (2022), pp. 17—21
DOI: 10.2478/sh-2022-0002

Back to the Future: The Rise of Human Enhancement and Potential Applications for Space Missions

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Abstract:
Rapid advances in biology, electronics, computer and data science have turned invention into products, changing the lives and lifestyles of millions of people around the world. This mini-review will describe some remarkable progress made over the last 10 years which serves both healthy individuals and patients alike. With a forward looking lens towards long term space missions and the potential colonisation of the Moon and Mars, we discuss three technologies under development. We conclude with a distant looking perspective on the prospect of gene mediated human enhancement and highlight the importance of aligning benefit for people on Earth with goals for future space missions and the need to establish regulatory and ethical guidelines.
Keywords: uman enhancement, gene therapy, gene editing, smart skin, brain-computer interface, prosthetic limbs, wearable devices, exoskeleton.

1. Introduction

As defined by the SIENNA project, human enhancement is: “the process of positively augmenting our abilities, permanently or temporarily. It includes any technology that expands or positively alters our capabilities or appearance: drugs, hormones, implants, genetic engineering or some surgeries" [1], [2].

In the early and middle 2000s, many concepts were progressed to products; some to restore function such as prosthetic limbs, cochlear implants, pharmaceutical [3] and gene mediated interventions [4], and others to augment human performance such as wearable devices [5]. More recently, advances have been made to support the restoration of sight and mobility, co-ordination and life-style convenience with the development of retinal implants – the bionic eye [6], brain-computer interface modalities [7] and smart skin using implanted radio frequency identification tags [8]. Selected examples of biological, cognitive and mechanical enhancements and overlaps in the underlying scientific disciplines are illustrated in Figure 1, with those highlighted in green text further depicted in Figures 2 and 3. It is widely believed that artificial intelligence (AI) has a central role to play in a post-human future [9].

Prior to 2011, prosthetic limbs tended to be clumsy, unsightly and provided sub-optimal co-ordination and mobility. Since the development of the modular prosthetic limb by the Defense Advanced Research Projects Association (DARPA) for Johns Hopkins University [10], proto-typing and evaluation [11] – [12] and the availability of life-like covers from companies such as Dorset Orthopaedica, performance and acceptability for the end user has been revolutionised. The development of virtual reality (VR) headsets which create an immersive experience can help educate and entertain consumers, has optimal uptake in technologically adept people [13] and may be associated with health concerns when used excessively [14]. Finally, development of smart watches, in particular the Apple Watch has many applications for positive monitoring of human health [15], is continuously under evaluation [16] and may inform the user of their current health status and whether intervention is required.

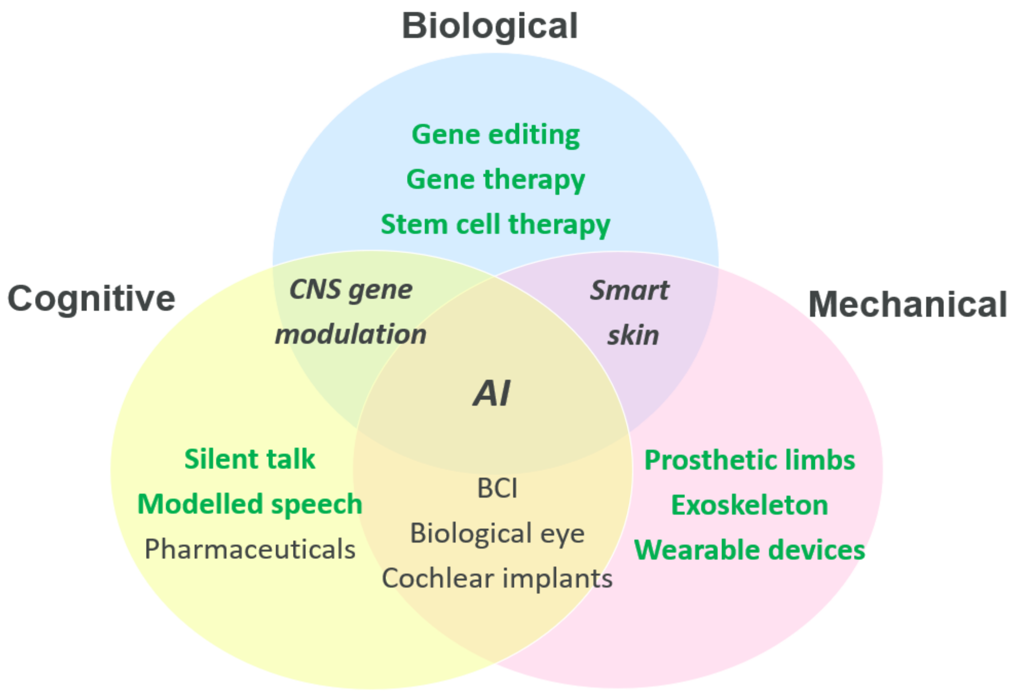

Figure 1. Venn diagram illustrating selected modalities and products and the overlap of supporting scientific disciplines. CNS: central nervous system, BCI: brain-computer interface, AI: artificial intelligence.

With a view to future developments, DARPA is developing an enhancement which may lead to the possibilities of non-vocal communication [17]. Through analysis of neural signals, brain activity is mapped using an electroencephalogram (EEG), with the aim of aligning specific EEG patterns to thoughts and given enough commonality between people, transmitting the signals to a receiver. This application may have utility in military campaigns and in extreme environments, for example in space where a synthesis of thoughts from multiple participants may be required to rapidly assess a situation and instigate an action.

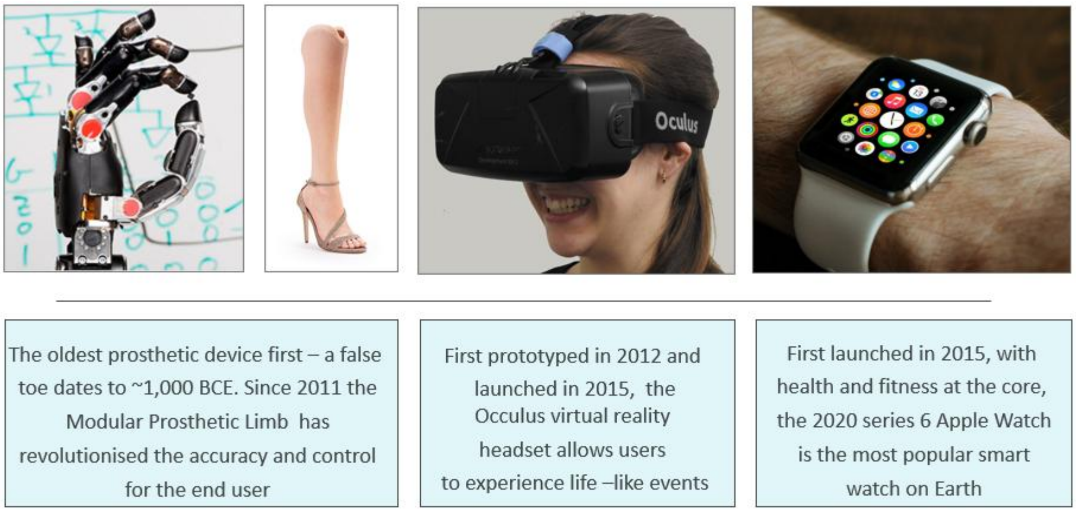

Figure 2. Selected advances in human enhancements between 2011 and 2015. Images: credit DARPA, Dorset Orthopaedica and PIXABAY.

A further example of a communication enhancement is that being developed by Braided Communications who offer a tool for seamless and meaningful communication in contexts where there are large signal latencies, such as deep space exploration with, for example, up to a 22 min delay in receipt of a transmitted signal from Earth to Mars [18].

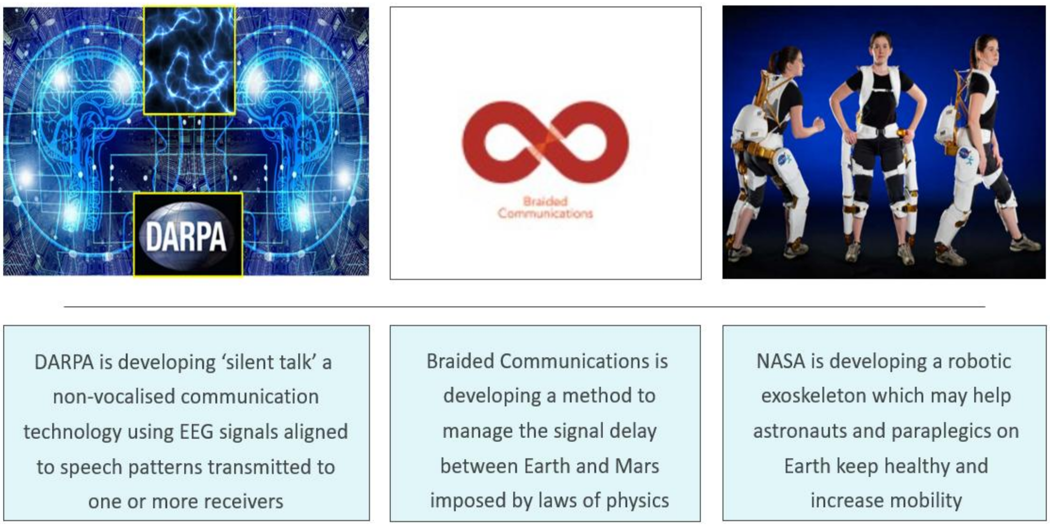

Figure 3. Selected future looking enhancements which benefit astronauts. EEG: electroencephalogram. Images: credit PIXABAY, Braided Communications and NASA.

This system may optimise communication supporting operational effectiveness for safety, medical and social exchanges with mission control, friends and family. Further details of the technology are expected in late 2021. Finally, the development of lower limb exoskeletons has received much attention since the early 2000s. In particular, this has been of benefit to people with disabilities especially since the metabolic barrier has been overcome reducing the metabolic cost of walking and running versus without a device [19], although design considerations need to be taken into account, potentially via a regulatory framework [20]. Within the context of space travel, National Aeronautics and Space Association (NASA) has developed the X1 robotic exoskeleton [21] which in addition to maintaining astronaut health in microgravity, may provide strength augmentation for astronauts during extra-vehicular activities and incorporate connectivity to record and transmit data in real-time to mission controllers on Earth. This may further inform on any remedial steps to be taken to maintain astronaut health.

2. Conclusion

Astonishing progress has been made over the last decade in products which may restore or augment human function. Advances in gene editing technology spurred on by numerous human clinical trials [22] may make it possible to genetically enhance human beings. With the stated aim of Mars colonization by the early 2030s, it is essential to progress the science for all modalities of human enhancement with both enthusiasm and caution. Society has a duty to ensure the need for compliance to and adherence with strict regulatory and ethical guidance, and to recognise both the challenges posed and the potential good for mankind if acceptable solutions can be found and enacted [1] – [3], [20], [23], [24]. With the oldest prosthetic dating back to ~1,000 BCE and stereoscopic images in the late 1830s as precursors for modern VR, we can look back to the future and a very exciting time awaits us all on Earth and in space.

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