"An Ontology of Neuroprostheses as Instruments of 'Cyborgization': Portals to the Experience of Posthumanized Digital-Physical Worlds," Chapter Three in Gladden, Matthew E., Neuroprosthetic Supersystems Architecture, pp. 113-45. Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-07-8 (print edition) and 978-1-944373-08-5 (ebook).

Chapter Three

An Ontology of Neuroprostheses as Instruments of 'Cyborgization':

Portals to the Experience of Posthumanized Digital-Physical Worlds

Abstract. The incorporation of a neuroprosthetic device into one's being at the physical, cognitive, and social levels constitutes a form of 'cyborgization' that imposes new constraints on one's existence while simultaneously opening a path to new forms of experience. This text explores the boundaries of this qualitatively novel form of being by formulating an ontology of the neuroprosthesis as an instrument that shapes the way in which its human host experiences and acts within emerging posthumanized digital-physical ecosystems.

The ontology addresses four main roles that a neuroprosthetic device may play in this context. First, a neuroprosthesis may serve as a means of human augmentation by altering the cognitive and physical capacities possessed by its host. Second, it may manipulate the contents of information produced or utilized by its human host. Third, a neuroprosthesis may shape the manner in which its host inhabits a digital-physical body and external environment. And finally, a neuroprosthesis may regulate the autonomous agency possessed and experienced by its host.

The development and use of such an ontology can allow researchers to better understand the psychological, social, and ethical ramifications of such technologies and can enable the architects of neuroprosthetic systems and the digital-physical ecosystems within which their human hosts operate to formulate principles of design and management that minimize the dangers and maximize benefits for the neuroprosthetically augmented inhabitants of such environments.

Introduction

The previous chapters have presented an ontology of the neuroprosthesis as a computing device and as a biocybernetic instrument that becomes integrated into the neural circuitry of a human organism in order to participate

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in processes of sensation, cognition, and motor action. In this chapter, we advance this exploration of the nature of neurocybernetic technologies by developing an ontology of the neuroprosthesis as a means for the 'cyborgization' of human beings that shapes how such individuals experience posthumanized digital-physical worlds.[1]

An Overview of Neuroprostheses

A neuroprosthesis may be defined as *an artificial device that is integrated into the neural circuitry of a human being* to create a neurocybernetic host-device system that possesses both human and computerized elements.[2] In principle, it is possible for neuroprostheses to be either 'invasive' (i.e., surgically implanted in the brain of a human host) or 'non-invasive' (e.g., consisting of an external device worn by a human host); however, it currently remains quite challenging to develop non-invasive technologies that can become fully integrated into the neural circuitry of a human being.[3] According to the definition employed in this text, contemporary neuroprostheses can thus typically be identified with invasive 'neural implants.' Devices involving non-invasive technologies such as EEG or fMRI are likely to be classified more generally as brain-computer interfaces (BCIs) or brain-machine interfaces (BMIs) rather than neuroprostheses.

[1] Here the term 'cyborgization' is used to describe the process by which a human host incorporates artificial biocybernetic components into his or her body, thereby becoming a cyborg. For use of the term in this context, see, e.g., Maguire & McGee, "Implantable Brain Chips? Time for Debate" (1999); Koltko-Rivera, "The Potential Social Impact of Virtual Reality" (2005); Novakovic et al., "Artificial Intelligence and Biorobotics: Is an Artificial Human Being Our Destiny?" (2009); and Nayar, *An Introduction to New Media and Cybercultures* (2010).

The term 'cyberization' is also sometimes used to describe the process of cyborgization. However, 'cyberization' is also used in a broader or alternative sense to refer to processes by which a human being becomes proficient in the use of (and perhaps psychologically and socially dependent on) – rather than physically integrated into – forms of electronic information and communications technology. When referring to the use of ICT such as email, social media, or computer gaming platforms, the term 'cyberization' does not imply that an individual has been subjected to physical biocybernetic augmentation; it is thus more appropriate to use the word 'cyborgization' when discussing the process of augmenting a host's body through the permanent incorporation of artificial biocybernetic components. For various uses of the term 'cyberization,' see, e.g., Miller, "Conclusion: Beyond the Human: Ontogenesis, Technology, and the Posthuman in Kubrick and Clarke's 2001" (2012); Baranyi et al., "Synergies Between CogInfoCom and Other Fields" (2015); and Ma et al., "Perspectives on Cyber Science and Technology for Cyberization and Cyber-Enabled Worlds" (2016).

[2] See Lebedev, "Brain-Machine Interfaces: An Overview" (2014), and Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016).

[3] See Gasson, "Human ICT Implants: From Restorative Application to Human Enhancement" (2012), p. 14, and Panoulas et al., "Brain-Computer Interface (BCI): Types, Processing Perspectives and Applications" (2010).

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Neuroprosthetic devices are commonly classified as either sensory, motor, bidirectional sensorimotor, or cognitive neuroprostheses.[4] At present, such devices primarily fill therapeutic roles, as a means of restoring some capacity that is absent as a result of injury or illness: for example, auditory brainstem implants and retinal prostheses are used to restore sensory functionality to those who have lost the ability to hear or see, thought-controlled wheelchairs are used to restore some degree of mobility to those who are paralyzed, and experimental neural bridges are being developed to restore memory function in those who are unable to access their long-term memory due to hippocampal damage.[5] However, efforts are underway to develop and implement neuroprosthetic technologies whose purpose is not to restore some capacity typically found in human beings but to grant their human hosts sensory, cognitive, and motor capacities that greatly exceed those possible for natural biological human beings.[6]

The Emergence of Posthumanized Digital-Physical Ecosystems

The world within which the human hosts and users of neuroprosthetic devices exist is an increasingly rich and complex array of digital-physical ecosystems that reflect the ongoing 'technologization' of humankind.[7] The processes of technologization are manifested in phenomena such as the increasing physical integration of human beings with electronic computerized systems, our expanding interaction with and dependence on robots and artificial intelligences, our growing immersion in virtual worlds, and the use of genetic engineering to design human beings as if they were consumer products.[8]

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[4] See Lebedev (2014).

[5] See, e.g., Cervera-Paz et al., "Auditory Brainstem Implants: Past, Present and Future Prospects" (2007); Weiland et al., "Retinal Prosthesis" (2005); Viola & Patrinos, "A Neuroprosthesis for Restoring Sight" (2007); and Soussou & Berger, "Cognitive and Emotional Neuroprostheses" (2008).

[6] Regarding the use of neuroprostheses for human enhancement, see, e.g., McGee, "Bioelectronics and Implanted Devices" (2008); Warwick & Gasson, "Implantable Computing" (2008); Gasson (2012); Gladden, "Neural Implants as Gateways to Digital-Physical Ecosystems and Posthuman Socioeconomic Interaction" (2016); and Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016).

[7] For a philosophical investigation (drawing on Actor-Network Theory) of ways in which human and nonhuman agents coexisting within digital-physical ecosystems might enter into 'symbioses' that are not simply metaphorical but are true symbioses at the physical, cognitive, and social levels, see Kowalewska, "Symbionts and Parasites – Digital Ecosystems" (2016).

[8] Processes of technologization are discussed as such in detail in Herbrechter, *Posthumanism: A Critical Analysis* (2013), and Gladden, *Sapient Circuits and Digitalized Flesh: The Organization as Locus of Technological Posthumanization* (2016). The relationship of posthumanism to the commercialization of the human entity is discussed in Herbrechter (2013), pp. 42, 150-52. For the analysis (and, in many ways, indictment) of technologization offered by critical posthumanism, see Herbrechter (2013), pp. 90, 19, and Gladden, *Sapient Circuits and Digitalized Flesh* (2016), p.

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These processes of technologization are themselves among the most visible manifestations of larger forces of posthumanization that are at work within contemporary society. Such posthumanization can be understood as a process by which society comes to include at least some intelligent personal subjects that are *not* natural biological human beings and which leads to a nonanthropocentric understanding of reality. It is anticipated that our emerging future will include many different sources of intelligence and agency that create meaning in the universe through their networks and relations:[9] such entities might include 'natural' human beings, genetically engineered human beings, human beings with extensive neurocybernetic augmentation, human beings dwelling in virtual realities, social robots, artificially intelligent software, nanorobot swarms, sentient or sapient networks, and hive minds that link human and artificial intellects to create a unitary collective intelligence. Within the digital-physical ecosystems that constitute the functional infrastructure of that posthumanized world, the 'bioagency' possessed by traditional human beings will act alongside (and mutually influence) the 'cyberagency' of artificial beings and 'collective agency' of networks and hive minds.[10]

Within this context, neuroprosthetic devices are expected to increasingly become gateways that allow their human hosts to more deeply experience, control, and be controlled by the structures and dynamics of such digital-physical ecosystems.[11] The development of an ontology of the neuroprosthesis as a catalyst for cyborgization, technologization, and posthumanization would not only allow researchers to better understand the psychological, social, and ethical ramifications of such technologies; it would also allow the architects of neuroprostheses and the digital-physical ecosystems in which they and their hosts participate to formulate principles of design and management that minimize the dangers and maximize the beneficial outcomes for neuroprosthetically augmented individuals operating within such ecosystems.

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[9] See Ferrando, "Posthumanism, Transhumanism, Antihumanism, Metahumanism, and New Materialisms: Differences and Relations" (2013), for an excellent analysis of this and other aspects of posthumanization.

[10] See Fleischmann, "Sociotechnical Interaction and Cyborg–Cyborg Interaction: Transforming the Scale and Convergence of HCI" (2009).

[11] See Gladden, "Neural Implants as Gateways" (2016).

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Figure 1: An Ontology of the Neuroprosthesis as Instrument of Cyborgization

I. The Neuroprosthesis as a Means of Human Augmentation

- **A.** Capacity-adding
  - **1.** Temporary addition
  - **2.** Permanent addition
- **B.** Capacity-enhancing
  - **1.** Temporary enhancement
  - **2.** Permanent enhancement
- **C.** Capacity-restoring
- **D.** Capacity-neutral
- **E.** Capacity-suppressing
  - **1.** Temporary suppression
  - **2.** Permanent eradication

II. The Neuroprosthesis as a Manipulator of Informational Content

- **A.** Content-providing
  - **1.** Content-detecting
  - **2.** Content-generating
  - **3.** Content-importing ('downlink')
  - **4.** Backup-restoring
- **B.** Content-translating
  - **1.** Content-encoding
  - **2.** Content-decoding
- **C.** Content-altering
  - **1.** Content-editing
  - **2.** Content-disrupting
  - **3.** Content-deleting
- **D.** Content-storing
- **E.** Content-transmitting
  - **1.** Content-exporting ('uplink')
    - **a.** Content-outstreaming
    - **b.** External archiving
  - **2.** Production of external device backup

III. The Neuroprosthesis as a Means of Inhabitation

- **A.** Embodiment: inhabitation of a material form
  - **1.** The host as cyborg: reshaping the physical body
    - **a.** Full-body cyborg
    - **b.** Partial cyborg
    - **c.** Extended cyborg
    - **d.** Sessile cyborg
    - **e.** Reverse cyborg
  - **2.** The host as avatar: shaping others' perceptions of the host
    - **a.** Cyberdouble
    - **b.** Cybermorph
- **B.** Embedding: inhabitation of an external environment
  - **1.** The world viewed through augmented reality
    - **a.** Overlaid information
    - **b.** Refracted reality
  - **2.** Occupancy of a virtual world
    - **a.** Degree of immersion
      - *i.* Maximal immersion
      - *ii.* Partial immersion
    - **b.** Period of immersion
      - *i.* Temporary immersion
      - *ii.* Long-term immersion
    - **c.** Cognizance of immersion
      - *i.* Recognized immersion
      - *ii.* Unrecognized immersion

IV. The Neuroprosthesis as a Regulator of Agency

- **A.** The neuroprosthesis as agent
  - **1.** Neuroprostheses possessing agency
  - **2.** Neuroprostheses lacking their own agency
- **B.** The neuroprosthesis as instrument of external agency
- **C.** The neuroprosthesis as modulator of a host's human agency
  - **1.** Agency-realizing neuroprostheses
  - **2.** Agency-extending neuroprostheses
  - **3.** Agency-complementing neuroprostheses
  - **4.** Agency-controlling neuroprostheses
  - **5.** Agency-enhancing neuroprostheses
  - **6.** Agency-impairing neuroprostheses
  - **7.** Agency-eradicating neuroprostheses
- **D.** The neuroprosthesis as hive mind infrastructure
  - **1.** The hive mind as sensorimotor network
  - **2.** The hive mind as facilitator of internal dialogue
  - **3.** The hive mind as unitary collective intelligence

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Developing an Ontology of the Neuroprosthesis as an Instrument of Cyborgization

The following sections develop an ontology of the neuroprosthesis as an instrument of cyborgization that shapes the manner in which its human host inhabits posthumanized digital-physical worlds. As delineated in Figure 1, the ontology addresses four main aspects of neuroprosthetic devices and the host-device systems that they form through structural and functional integration with their human hosts. First, a neuroprosthesis may serve as a means of human augmentation by altering the cognitive and physical capacities possessed by its host. Second, it may manipulate the contents of information produced or utilized by its human host. Third, a neuroprosthesis may shape the manner in which its host inhabits a digital-physical body and external environment. And finally, a neuroprosthesis may regulate the autonomous agency possessed and experienced by its host. These elements of the ontology are developed in detail below.

I. The Neuroprosthesis as a Means of Human Augmentation

Neuroprosthetic devices vary in the extent to which they enhance the naturally occurring capacities found within a typical biological human being. A device may add some new type of capacity that is not found in natural biological human beings; enhance or expand an existing capacity; restore some typical human capacity that is absent in a particular individual; suppress an existing capacity; or have no effect on the sensory, motor, and cognitive capacities possessed by a device's host.[12]

A. Capacity-adding

A neuroprosthetic device may grant its host some capacity that is not typically found in natural biological human beings. Examples might include a sensory neuroprosthesis gives its host the ability to perceive radio waves or a motor neuroprosthesis that allows its host to produce a particular pattern of visible light from an implanted photon emitter whose surface is exposed to the external environment (e.g., an LED display embedded in the host's arm). Such new capacities may be temporary or permanent.

[12] Various aspects of the use of neuroprostheses for human augmentation and enhancement is discussed, e.g., in *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science*, edited by Bainbridge (2003); Merkel et al., "Central Neural Prostheses" (2007); McGee (2008); Gasson (2012); Warwick, "The Cyborg Revolution" (2014); and Gladden, "Neural Implants as Gateways" (2016).

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1. Temporary Addition

In some cases it may not be practical or desirable for a neuroprosthesis to add a new capacity that is continuously manifested. For example, a cognitive neuroprosthesis that grants its host savant skills by electromagnetically disrupting the normal behavior of the left anterior temporal lobe[13] may do so at the cost of creating problems with other cognitive processes such as those involving shared attention, social cognition, and empathy. In that case, it may be most appropriate for the device to only be activated for brief periods of time when its functionality is required. Similarly, an artificial eye that provides its host with infrared vision or augmented reality displays may only activate these features when they are needed for a particular reason, so that the device's host can enjoy unimpeded normal visual perception at other times.[14] The use of neuroprostheses to provide only the sporadic and temporary addition of a capacity may be especially warranted in the case of devices that directly affect the functioning of the brain or other critical organs and whose long-term side-effects are not well understood.[15]

2. Permanent Addition

Some neuroprosthetic devices provide their host with a new capacity that is permanently active. For example, a sensory neuroprosthesis that records incoming visual sense data and wirelessly transmits it to an external system to create a backup copy may be running continuously, as it is not knowable in advance which visual experiences might later prove to be noteworthy and

[13] Damage to the left temporal lobe can cause adults to experience 'acquired savant syndrome,' in which they suddenly acquire savant skills; recent research suggests that it is possible to temporarily and artificially produce savant skills in individuals by temporarily disrupting the functioning of the left anterior temporal lobe by means of neurotechnologies such as transcranial magnetic stimulation (TMS). An implantable neuroprosthesis that is capable of briefly disrupting the behavior of the left temporal lobe might be able to temporarily provide its host with savant skills when needed, while at other times remaining inactive in order to avoid producing the deficits in shared attention, social cognition, and empathy that often accompany damage to the left temporal lobe. For a discussion of the possibility of inducing savant skills through the application of TMS, see Snyder et al., "Savant-like skills exposed in normal people by suppressing the left fronto-temporal lobe" (2003), and Snyder, "Explaining and inducing savant skills: privileged access to lower level, less-processed information" (2009).

[14] Regarding future neuroprosthetic devices that may grant such capacities, see, e.g., Warwick (2014); Gasson et al., "Human ICT Implants: From Invasive to Pervasive" (2012); and Merkel et al. (2007).

[15] Regarding the potential critical health impacts of implantable neuroprostheses, see *ISO 27799:2016, Health informatics – Information security management in health using ISO/IEC 27002* (2016); Ankarali et al., "A Comparative Review on the Wireless Implantable Medical Devices Privacy and Security" (2014); and Gladden, "Information Security Concerns as a Catalyst for the Development of Implantable Cognitive Neuroprostheses" (2016).

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merit future replay or analysis.[16] The use of neuroprostheses to provide permanent, ongoing enhancement of a host's capacities may be especially warranted, for example, in cases where the repeated activation and deactivation of an enhancement might cause significant psychological or physical stress, create risks to a host's health, or cause other disruptions.[17]

B. Capacity-enhancing

A neuroprosthetic device may enhance some capacity in a qualitative or quantitative way to exceed what is typically possible for natural biological human beings but without granting its user an entirely new capacity. Examples might include an auditory prosthesis which allows its user to hear faint sounds whose volume falls just below the threshold of what the ear can normally detect. Such enhancement may be temporary or permanent in nature.[18]

1. Temporary Enhancement

Some enhancements may only be activated sporadically and temporarily. For example, an artificial eye might possess physical or digital mechanisms that amplify the available light and allow its user to discern environmental details in very low-light conditions; such an enhancement would be useful if it were nighttime and the user were attempting to navigate the environment, but it could be disruptive and dangerous if the user walked out into a bright sunlit environment with the enhancement still active and were blinded by its effects.[19]

[16] The use of neuroprostheses for sensory recording and playback is discussed, e.g., in Merkel et al. (2007); Robinett, "The consequences of fully understanding the brain" (2002); McGee (2008), p. 217; and Gladden, *Sapient Circuits and Digitalized Flesh* (2016).

[17] For the possibility that use of a neuroprosthesis may create dependencies that would result in psychological, physical, economic, or social harm to its human host if use of the device were to be discontinued, see Bostrom & Sandberg, "Cognitive Enhancement: Methods, Ethics, Regulatory Challenges" (2009), p. 323; McGee (2008), p. 213; Koops & Leenes, "Cheating with Implants: Implications of the Hidden Information Advantage of Bionic Ears and Eyes" (2012), p. 125; Gladden, "Neural Implants as Gateways" (2016); and Gladden, "Managing the Ethical Dimensions of Brain-Computer Interfaces in eHealth: An SDLC-based Approach" (2016).

[18] Note that as discussed here, 'enhancement' is defined in relation to the typical abilities of a natural biological human being, not in relation to the specific user who is receiving a device. For example, a motor neuroprosthesis that restores typical voluntary hand movement to an individual who has lost that ability due to injury or illness would more appropriately be seen as a restorative or therapeutic device rather than one that brings about human enhancement – although its host would experience it has having 'enhanced' his or her capacities beyond what existed prior to the device's activation.

[19] The use of neuroprostheses to grant abilities such as telescopic or zoom vision is discussed in Gasson et al. (2012); Merkel et al. (2007); and Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016).

2. Permanent Enhancement

Some enhancements may be permanently active. For example, an implantable cognitive neuroprosthesis that provides enhanced long-term memory functionality and which is deeply integrated into the brain structures of its host and powered by its host's internal biological processes may be continuously active following its implantation.[20]

C. Capacity-restoring

A neuroprosthetic device may restore or provide to its host some capacity that is typically found in natural biological human beings but which the host lacks (perhaps as a result of illness or injury). An example would include a sensorimotor prosthetic robotic arm that restores typical sensory and motor capacity to an individual who has lost one of his or her natural biological arms in an accident.[21]

D. Capacity-neutral

It is possible for a neuroprosthetic device to have no net impact on the sensory, motor, or cognitive capacities possessed by its host. For example, an individual might conceivably decide for purely aesthetic reasons to replace one of his or her natural biological body parts with an artificial neuroprosthesis that looks different but possesses the same functional capacities.[22]

E. Capacity-suppressing

A neuroprosthetic device may suppress capacities naturally possessed by its human host. For example, a cognitive neuroprosthesis that treats insomnia by inducing a sleeping state in its host could be understood as suppressing

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[20] The 'memory prostheses' whose development is described in Soussou & Berger (2008) serve as a bridge between neurons that spans a damaged area within the hippocampus; future devices of this sort might be designed to operate continuously. For a discussion of technologies that might allow future implanted neuroprostheses to be powered by means of their hosts' own internal biological processes, see, e.g., Mitcheson, "Energy harvesting for human wearable and implantable bio-sensors" (2010); Zebda et al., "Single glucose biofuel cells implanted in rats power electronic devices" (2013); and MacVitte et al., "From 'cyborg' lobsters to a pacemaker powered by implantable biofuel cells" (2013).

[21] For an overview of the current state and anticipated future development of neuroprosthetic robotic limbs, see Farina & Aszmann, "Bionic limbs: clinical reality and academic promises" (2014), and Pazzaglia & Molinari, "The embodiment of assistive devices – from wheelchair to exoskeleton" (2016). For a broader discussion of therapeutic applications of neuroprosthetics, see, e.g., *Implantable Neuroprostheses for Restoring Function*, edited by Kilgore (2015), and Sanchez, *Neuroprosthetics: Principles and Applications* (2016).

[22] For cybernetic augmentation as a form of artistic expression, see, e.g., *The Cyborg Experiments: The Extensions of the Body in the Media Age*, edited by Zylinska (2002).

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its host's ability for conscious awareness.[23] Such suppression may be temporary or permanent in nature.

1. Temporary Suppression

A neuroprosthesis may temporarily suppress some capacity within its human host. For example, a cognitive neuroprosthesis that suppresses its host's natural biological mechanisms for experiencing fear and anxiety may be activated when a soldier, aircraft pilot, or surgeon is about to perform some highly dangerous and sensitive maneuver, in order to allow him or her to act without any psychological and physical disruptions caused by nervousness – but at other times the device may be inactive, in order to allow the host's natural fear responses to prevent him or her from performing actions that are reckless and inappropriate in everyday life.

2. Permanent Eradication

A neuroprosthesis may permanently destroy some capacity previously possessed by its host. Note that such an outcome need not be an intentional effect desired by the device's designer, operator, or host. For example, a neuroprosthesis implanted in the brain might as a side-effect of its operation produce heat, electromagnetic radiation, or toxic chemical emissions that gradually destroy individual neurons or larger brain structures in a way that cannot be reversed or repaired and which permanently deprives its host of some sensory, motor, or cognitive capacity.[24]

II. The Neuroprosthesis as a Manipulator of Informational Content

A neuroprosthetic device may produce, receive, store, transmit, manipulate, or otherwise affect particular types of information that serve as the input or output of its host's sensory, cognitive, or motor processes. Such information might be found in sense data received from the environment, memories stored within the brain of the device's host, motor instructions that control the behavior of an effector, or in other components and contexts.[25] Below

[23] As noted earlier in the case of TMS used to artificially induce savant skills, the artificial suppression of some of the brain's capacities might simultaneously generate or enhance other capacities.

[24] The dangers of neuroprostheses that may be toxic or degrade over time in the body are noted in McGee (2008), pp. 213-16, and Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016).

[25] Indeed, one of the essential characteristics that distinguishes implantable neuroprostheses from other implantable medical devices (such as a prosthetic hip) is that the former are sophisticated pieces of *information and communications technology* (or ICT) – although even seemingly electronically 'inert' objects such as artificial hip joints, breast implants, or dental prostheses may

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we discuss key roles that a neuroprosthetic device might play in shaping the nature and contents of such information.

A. Content-providing

There are a variety of ways in which a neuroprosthesis may provide informational content for a sensory, cognitive, or motor process.

1. Content-detecting

A neuroprosthesis may detect and capture information that is naturally existing within its environment and which did not need to be purposefully engineered or prepared in order to be detected by the device. A cochlear implant or retinal prosthesis that receives sense data in the form of environmental auditory or visual stimuli would be an example of such a neuroprosthesis.[26]

2. Content-generating

A neuroprosthetic device may autonomously generate content relating to a sensory, cognitive, or motor process – perhaps through the use of a software algorithm or the functioning of an artificially intelligent neural network. Such an approach might be used, for example, by a neuroprosthesis that is part of an immersive virtual reality system in order to generate the sense data corresponding to the virtual world to be experienced by the device's host.[27]

3. Content-importing ('Downlink')

A neuroprosthesis may import content in a specially prepared form that is immediately usable by the device from some external system that exists outside of the device and its human host. Such a neuroprosthesis would thus employ a 'downlink' by which information flows into itself from that outside source. Such importing may involve the receipt of an ongoing stream of real-

in the future increasingly include RFID chips used to facilitate device identification and diagnostics. Regarding RFID-enabled hip and breast implants, see Gasson, "Human ICT Implants" (2008), p. 22; for RFID-enabled dental implants, see Chang et al., "RFID applied in recognition and identification for dental prostheses" (2012). A key aspect of the nature of neuroprostheses as ICT is the need to maintain the information security of such devices and their host-device systems; that can be understood using InfoSec schemas such as the 'CIA Triad' relating to the confidentiality, integrity, and availability of information. See Gladden, *The Handbook of Information Security for Advanced Neuroprosthetics* (2015), and Gladden, "Information Security Concerns as a Catalyst for the Development of Implantable Cognitive Neuroprostheses" (2016).

[26] For a discussion of these types of sensory neuroprostheses, see Dormer, "Implantable electronic otologic devices for hearing rehabilitation" (2003); Gasson et al. (2012); Ochsner et al., "Human, non-human, and beyond: cochlear implants in socio-technological environments" (2015); Weiland et al. (2005); and Viola & Patrinos (2007).

[27] Regarding the potential use of implantable neuroprostheses as components of an augmented or virtual reality system, see, e.g., Sandor et al., "Breaking the Barriers to True Augmented Reality" (2015), pp. 5-6, and Gladden, *Sapient Circuits and Digitalized Flesh* (2016).

time data (i.e., 'content instreaming') or the periodic reception of a discrete file. The imported content might, for example, provide sense data to a sensory neuroprostheses or remote instructions to govern the actions of a motor neuroprosthesis.[28] Note that the neuroprosthetic device, its human host, and its operator may or may not recognize the fact that information is being imported from an external source; in the case of a neuroprosthesis whose information security has been compromised by an adversary, the existence of the downlink might be purposefully disguised.[29]

4. Backup-restoring

A neuroprosthesis may possess the capacity of reverting to an earlier functional state by loading a backup of stored data that is stored either remotely or within the device itself.[30]

B. Content-translating

A neuroprosthetic device may translate content from one form to another. For example, a sensory neuroprosthesis may perform a process of transduction by which some environmental stimulus (such as photons or sound waves) is converted into digital data for transmission to a computer for processing or into electrochemical signals for transmission to a biological neuron.[31]

1. Content-encoding

Particular examples of content translation by a neuroprosthetic device include the encoding of data for purposes of compression, encryption, storage,

[28] For the potential capacity of sensory neuroprostheses to receive live streams of sense data from a remote source, see Koops & Leenes (2012), pp. 115, 120, 126. Regarding the remote control of neuroprostheses (e.g., by a team of medical personnel controlling a device in order to deliver telemedicine), see Gasson (2012) and Gladden, *The Handbook of Information Security for Advanced Neuroprosthetics* (2015).

[29] For example, the possibility that false data might be supplied to a sensory neuroprostheses is raised in Koops & Leenes (2012); McGee (2008); and Gladden, *Sapient Circuits and Digitalized Flesh* (2016).

[30] Creating backup copies of information is a fundamental technique of information security; however, for neuroprostheses that store and process data in the form of a biological or biomimetic neural network, it may be impractical or even impossible to back up the devices' data in its entirety to a physically secure location in order to ensure its long-term availability. See *ISO 27799:2016* (2016) and Gladden, "Information Security Concerns as a Catalyst for the Development of Implantable Cognitive Neuroprostheses" (2016).

[31] Natural biological processes for the transduction of sense data are discussed in Smith, *Biology of Sensory Systems* (2008), pp. 1-30, and Møller, *Sensory Systems: Anatomy and Physiology* (2014), pp. 29-62.

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or error correction to maintain integrity during transmission through a noisy channel.[32]

2. Content-decoding

An example of content decoding facilitated by a neuroprosthetic device would be the use of a mnemoprosthesis to retrieve and interpret particular memories stored in the brain's natural biological systems for short-term or long-term memory by detecting relevant neural structures and activity.[33]

C. Content-altering

A neuroprosthetic device may modify the contents of data at rest or in transit in a way that does not simply translate the data from one form or medium to another and which results in a loss of integrity of the original information.[34]

1. Content-editing

For example, a neuroprosthetic device may purposefully edit the content of some message, file, or signal in a purposeful and targeted way. An artificial eye might thus edit portions of the visual data presented to the mind of its human host in order to add specialized supplementary information through an augmented reality display.[35]

2. Content-disrupting

A neuroprosthetic device may alter the information present within a medium in a way that does not purposefully replace the information with some particularly meaningful targeted contents but simply disrupts it in a way that results in a permanent loss of the information.

3. Content-deleting

A neuroprosthetic device may delete information stored within itself or within connected biological systems, either as a normal part of its functioning or as an exceptional action. For example, a mnemoprosthesis may be capable

[32] For an overview of such practices, see, e.g., Neubauer et al., *Coding Theory: Algorithms, Architectures and Applications* (2007); Sayood, *Introduction to Data Compression* (2012); and Stallings, *Cryptography and Network Security: Principles and Practice* (2017).

[33] The brain's mechanisms for memory encoding and retrieval are discussed in Schwartz, *Memory: Foundations and Applications* (2014).

[34] The meaning of information 'integrity' within the context of information security is discussed in Parker, "Toward a New Framework for Information Security" (2002), p. 125.

[35] See, e.g., Sandor et al. (2015).

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of erasing specific memories stored within the natural biological neural network of its human host's brain.[36]

D. Content-storing

A neuroprosthetic device may store information at rest. Such information may have been written to the device by its designers or operators prior to its activation or received or generated by the device during the time of its operation. Such contents may only be stored on the device temporarily (e.g., raw sense data that is stored momentarily before being processed) or permanently (e.g., operating system files). Information may be stored in the form of conventional binary digital files that can be accessed and interpreted by ordinary desktop computers, or they may be stored as connection and activation patterns within a physical neural network in a form that is difficult or impossible for external systems to access and interpret.[37]

E. Content-transmitting

A neuroprosthetic device may physically transmit information to external systems or components in the form of a digital or analogue signal.

1. Content-exporting ('Uplink')

A neuroprosthetic device may export content to some external system in a specialized form that is immediately usable by that system. Such a neuroprosthesis utilizes an 'uplink' by which information emanates from the device. Such exporting may involve the transmission of an ongoing stream of real-time data or the periodic generation and transmission of a discrete file. Such transmissions may or may not contain sufficient data to allow their recipients to restore the device to an earlier functional state in case of device failure. Note that the neuroprosthetic device, its human host, and its operator may or may not recognize the fact that information is being exported to an

[36] In some circumstances it might conceivably be desirable for a neuroprostheses to disrupt or delete undesirable memories stored within a brain's natural biological memory systems – e.g., because existence of the memories produces some unwanted psychological impact for the device's host or because the information is of a highly sensitive nature and was needed by the host only temporarily for the performance of a task that is now complete. The development of neuroprostheses capable of such actions might build on experimental technologies already used to successfully erase memories in mice. See Han et al., "Selective Erasure of a Fear Memory" (2009).

[37] Various approaches to binary digital data storage are discussed in *Information Storage and Management: Storing, Managing, and Protecting Digital Information in Classic, Virtualized, and Cloud Environments* (2012). The human brain's mechanisms for storage of long-term memories are discussed in Dudai, "The Neurobiology of Consolidations, Or, How Stable Is the Engram?" (2004), and Schwartz (2014).

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external system; especially in the case of a neuroprosthesis whose information security has been compromised by an adversary, the existence of the uplink might be purposefully concealed by its creator.[38]

a. Content-outstreaming

A particular form of uplink is content-outstreaming, by which an ongoing stream of real-time data is transmitted to an external system. Such an uplink might, for example, allow online viewers around the world to vicariously experience reality 'through the eyes' of a human performance artist whose artificial eyes are continually broadcasting the sense data that they receive so that it can be experienced by others using virtual reality equipment.[39]

b. External Archiving

Another form of uplink involves content archiving, by which information received or generated by a device is periodically copied to an external system for potential future use by the device's human host or operator or by the device itself. For example, a cochlear implant might periodically transmit to its external support system an audio file containing the previous ten hours of auditory stimuli detected by the device. The device's host could later 'play back' particular conversations or other auditory experiences at will by downloading the correct archive file into the cochlear implant's internal computer.[40] Note that archived content does not necessarily constitute a backup file, as it may be fragmentary in nature and may not allow full restoration of a neuroprosthetic device to an earlier functional state.

2. Production of External Device Backup

A neuroprosthetic device may transmit information to an external system in the form of a single periodically generated file or an ongoing stream of data that can be used to restore the device to its current or an earlier functional state, should the device suffer a failure such as that caused by a power outage or physical damage. Note that the device itself may or may not possess the

[38] For the possibility that a hacker, computer virus, or other agent may be able to steal data contained in a neuroprosthesis or use the device to gather data (potentially including the contents of the thoughts, memories, or sensory experiences of the device's human host or others), see McGee (2008), p. 217; Koops & Leenes (2012), pp. 117, 130; Gasson (2012), p. 21; and Gladden, *The Handbook of Information Security for Advanced Neuroprosthetics* (2015).

[39] For a discussion of such possibilities, see Gladden, *The Handbook of Information Security for Advanced Neuroprosthetics* (2015), p. 291.

[40] The potential development of neuroprostheses that could allow 'playback' of recorded or previously experienced information is discussed in Merkel et al. (2007); Robinett (2002); and McGee (2008), p. 217.

capacity to autonomously retrieve remote backup files and restore itself; such actions may need to be manually performed by an external operator.[41]

III. The Neuroprosthesis as a Means of Inhabitation

Neuroprostheses can play powerful roles in transforming the way in which a host's mind is embodied within a particular corporeal form and the manner in which that body is embedded within an external environment.[42]

Distinguishing Primary ('Real') and Secondary ('Virtual') Physical Worlds

In order to appropriately analyze the potential involvement of neuroprostheses in their host's processes of embodiment and inhabitation of an environment, it is important to first develop a clear formulation of the difference between what are commonly referred to as 'real' and 'virtual' objects and phenomena. In everyday speech, a distinction is commonly made between the 'real world' in which human beings and their bodies, homes, automobiles, and computing devices exist and a 'virtual world' that exists only within a computer and which is experienced, for example, by staring at a computer monitor or wearing a VR headset. Implicit within this popular understanding is the notion that the 'real world' is one of tangible physical objects and a 'virtual world' is non-physical, a world whose apparent physicality is only the illusory product of a carefully arranged presentation of sense data.[43]

However, from the perspective of neuroprosthetic supersystems architecture, such a popular conception pitting 'the real' versus 'the virtual' is not only insufficient but even incorrect. A neuroprosthesis that immerses its human host in a virtual reality environment and provides its host with the experience of possessing a radically nonhuman body (e.g., a body in the form of a robotic octopus or a floating sphere of light) is not 'non-physical' in nature: after all, the neuroprosthetic device is made of physical components that are created

[41] The importance of regular creation of backup files is discussed in *NIST Special Publication 800-53, Revision 4: Security and Privacy Controls for Federal Information Systems and Organizations* (2013), p. F-87, and *ISO 27799:2016* (2016).

[42] There is a well-developed literature on the subject of embodied embedded cognition from perspectives such as human psychology, philosophy of mind, and robotics. See, e.g., Wilson, "Six views of embodied cognition" (2002); Anderson, "Embodied Cognition: A field guide" (2003); Sloman, "Some Requirements for Human-like Robots: Why the recent over-emphasis on embodiment has held up progress" (2009); and Garg, "Embodied Cognition, Human Computer Interaction, and Application Areas" (2012).

[43] Different approaches to defining virtual reality are discussed, e.g., in Heim, *The Metaphysics of Virtual Reality* (1993); *Communication in the Age of Virtual Reality*, edited by Biocca & Levy (1995); *Cybersociety 2.0: Revisiting Computer-Mediated Communication and Community*, edited by Jones (1998); Lyon, "Beyond Cyberspace: Digital Dreams and Social Bodies" (2001); Koltko-Rivera (2005); and Bainbridge, *The Virtual Future* (2011).

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and maintained through physical processes, and it interacts physically with the biological components of the host's nervous system. Moreover, even the nonhuman virtual body that the device fashions for its host is not non-physical in character; the nature of the virtual body's structure and behaviors is stored as data (e.g., a set of binary digital files) that is contained within some physical substrate, such as a hard drive, RAM chip, or physical neural network. Damage to that physical substrate would result in the alteration or loss of the virtual body experienced by the host, just as damage to the host's natural biological body would result in the alteration or loss of that 'real' body. And the host does not sense and control his or her virtual body by means of some telepathic or psychokinetic powers that are non-physical in nature: sense data from the virtual world is provided by means of electrochemical signals that are an observable element of the physical world and which must physically affect neurons within the host's biological body, and in order to manipulate his or her body the host must generate or manipulate physical phenomena (such as electrical activity or chemical neurotransmitters in the brain) that can be detected by physical components of the neuroprosthetic device.

The distinguishing characteristic of virtual bodies and virtual worlds is thus not that they are 'non-physical' or 'unreal' but that they possess a special *type* of physicality. A human being's natural biological body is characterized by the fact that its physical components share an isomorphic and direct causal relationship with the components of the body that is experienced by the mind of that person. For example, a human being can see and feel that she possesses a leg whose components occupy a particular space and create a particular shape, and indeed the person's biological body includes cells and other physical components that are arranged in such a pattern. On the other hand, a virtual body belonging to a human being is characterized by the fact that its physical components do not share an isomorphic and direct causal relationship with the components of the body that is experienced by the mind of that person. For example, a human being might see and feel that she possesses a leg whose components occupy a particular space and create a particular shape, but the physical components determining the shape and nature of her leg are in fact a set of electrons stored within the capacitors of a RAM module's integrated circuit within her neuroprosthetic device.

Instead of counterposing terms such as 'real' versus 'virtual' or 'physical' versus 'digital' to distinguish these differing constellations of structures and activities, this text will utilize the phrase '**primary physical world**' to refer to the isomorphic physical world that includes a human being's natural biological body and surrounding environment and the phrase '**secondary physical world**' to refer to an anisomorphic physical world that determines the nature of a

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virtual body and virtual world to be experienced by a human being.[44] Having delineated these terms, we can consider in more detail the ways in which a neuroprosthesis may mediate a mind's situation in and interaction with the world through the processes of embodiment and embedding.

A. Embodiment: Inhabitation of a Material Form

Every neuroprosthetic device impacts the manner in which its host is embodied within a particular corporeal form or 'body.' Insofar as a neuroprosthetic device is integrated into the physical neural circuitry of its human host, the neuroprosthesis by definition affects the structure and behavior of its host's body. Some neuroprostheses only seek to support or restore the typical functioning of a host's natural biological body, while others provide their host with an enhanced or transformed (and potentially radically nonhuman) body. Such transformation may involve replacing or dramatically altering a significant portion of the natural physical components of a host's biological body, or it may involve leaving the host's biological body largely intact but providing the host – and others – with an *experience* of the host's possession of an enhanced or transformed body within some virtual world.[45] The difference between altering the host's body as it exists within the primary physical world (i.e., the 'real' world) and as it exists in a secondary physical world (i.e., a 'virtual' world) can be understood as the difference between the existence of the host as cyborg and the host as digital avatar.

1. The Host as Cyborg: Reshaping the Physical Body

A neuroprosthetic device that replaces or supplements part of its host's original biological physical body with new physical components that are designed to interact directly with the external physical environment (e.g., through physical touch, grasping, manipulation, gestures, locomotion, and audible speech) constitutes an isomorphic neuroprosthesis and can be understood as providing its host – to a greater or lesser extent – with a physical cyborg body. Such a process of 'cyborgization'[46] might involve the replacement of a severely damaged biological limb with a robotic prosthetic replica,

[44] There is only one primary physical world, while there is a limitless number and variety of secondary physical worlds in which a device's human host might become immersed – as well as tertiary or further worlds. We thus speak of 'the' primary physical world but 'a' secondary physical world.

[45] For the extent to which neuroprosthetic devices or other devices can become incorporated into a host's body schema, see Gladden, "Cybershells, Shapeshifting, and Neuroprosthetics: Video Games as Tools for Posthuman 'Body Schema (Re)Engineering'" (2015), and Pazzaglia & Molinari (2016).

[46] For use of the term 'cyborgization' to describe such a process, see, e.g., Maguire & McGee (1999); Koltko-Rivera (2005); Novakovic et al. (2009); and Nayar (2010). The term 'cyberization'

the augmentation of a healthy biological eye through the integration of additional sensors that allow a host to detect infrared light, or the implantation into the brain of a brain-computer interface that allows a host to wirelessly interact with and remotely control computerized systems.

Depending on the physical nature of a host's cybernetic augmentation, the manner in which it was installed in the host's body, and the way in which it interacts with the host's cognitive processes, a host may or may not realize that he or she has become a cyborg through the addition of such cybernetic components.[47]

a. Full-body cyborg

It is possible for a human host to replace at most a portion of his or her body with artificial cybernetic components; at least some critical components of the host's natural biological brain must remain intact.[48] Thus a 'full cyborg' should be understood not as a human being whose body has been wholly replaced with artificial biocybernetic components but one whose biological body parts have been replaced with artificial biocybernetic components *to the greatest extent possible* without causing the death of the host or loss of his or her personal identity. It is not clearly known to what extent a process of cyborgization can be safely applied to an individual before his or her limit for the maintenance of cognitive and biological integrity is exceeded, the host's personal identity is irrevocably lost, and death ensues.[49]

is also sometimes used to describe this process by which a human host incorporates artificial biocybernetic components into his or her body, thereby becoming a cyborg. However, the term 'cyberization' is also used in a broader or alternative sense to refer to processes by which a human being becomes psychologically (rather than physically) integrated into electronic information systems such as immersive virtual reality systems through long-term use and sensorimotor experience. This latter sense of 'cyberization' does not imply that an individual has been subjected to physical biocybernetic augmentation; it may be thus more appropriate to use the word 'cyborgization' when discussing the process of augmenting a host's body through the permanent incorporation of artificial biocybernetic components. For various meanings of the term 'cyberization,' see, e.g., Miller (2012); Baranyi et al. (2015); and Ma et al. (2016).

[47] For the possibility that a human host may not realize that he or she has been implanted with an invasive neuroprosthesis, see Gladden, *The Handbook of Information Security for Advanced Neuroprosthetics* (2015).

[48] At a minimum, some critical components of a host's natural biological brain must remain intact for a device to interface with; otherwise – by definition – the device is not a neuroprosthesis that is integrated into the neural circuitry of its human host. A technological system that replaces every one of a host's natural biological neurons with synthetic copies might thus be described as a 'neurotechnology' but not a 'neuroprosthesis.' Through the application of sufficiently sophisticated artificial intelligence such a device might even replicate much of the behavior of the human brain that has served as its template, but the device could not be understood as 'interfacing' with that brain.

[49] The notion that an excessive degree of cybernetic augmentation might result in an individual's

A full-body cyborg may be able to function safely and effectively in environments that are inhospitable or even fatal to unaugmented human beings (such as those lacking breathable air or possessing extremely high or low temperatures, pressure, acceleration, or levels of light or sound), if his or her organs are replaced with artificial substitutes or alternatives whose capacities differ significantly from those of the typical natural biological human body.

b. Partial cyborg

A 'partial cyborg' can be understood as a human being whose body has undergone a degree of permanent biocybernetic augmentation that is less than the maximum possible for that person. In cases of minimal cyborgization, the amount of biocybernetic augmentation may be trivial and it may be debatable whether an individual can appropriately be considered a 'cyborg,' depending on the precise definition of the term that is employed. For example, an individual who has received a dental bridge will likely not be considered a cyborg, due to the device's passive nature and lack of bioelectronic functionality. A person who has lost a hand due to injury and been given a conventional prosthetic hand whose fingers do not move will also likely not be considered a cyborg due to the device's easily detachable and nonpermanent nature, its lack of bioelectronic functionality, and its lack of interaction with the person's nervous system. An individual who has received an implantable RFID chip may be considered a cyborg by some experts, given the device's permanent incorporation into its host's body and its electronic functionality; however, he or she may not be considered a cyborg by others because of the device's lack of integration into its host's sensory, motor, and cognitive structures and processes. An individual who has received an artificial cardiac pacemaker may be considered a cyborg because of the device's long-term implantation in the body and integration into the functioning of the body's organs or may not because of the fact that the device supplements rather than replaces a biological component of the host's body, the fact that some of its parts (e.g., its battery) must be periodically replaced, and the fact that it is used for purely medical purposes rather than purposes of human enhancement.

loss of biological integrity, personal identity, or human 'essence' is discussed, e.g., in Miah, "A Critical History of Posthumanism" (2008), pp. 73-74; Fukuyama, *Our Posthuman Future: Consequences of the Biotechnology Revolution* (2002); and Gladden, *Sapient Circuits and Digitalized Flesh* (2016). It may be hypothesized that the threshold of maximum possible cyborgization may vary between individuals (e.g., depending on their age and health); the threshold for human beings as a whole may conceivably also increase over time, as new technologies allow the safer and more effective replacement of additional biological body components with artificial replicas or alternatives and human organisms are genetically engineered to become more amenable to such technologies.

c. Extended cyborg

An extended cyborg is one whose artificial biocybernetic components do not replace natural biological components with functionally equivalent replicas but which add new (and potentially radically non-human) ones. Such a cyborg might possess physical elements such as wheels, gills, additional limbs, or additional eyes providing 360° vision. The extent to which a cyborg can possess a non-human morphology is studied by the field of body schema engineering.[50]

d. Sessile cyborg

A neuroprosthesis may take the form of a biocybernetic housing or life-support system within which its host's brain (and perhaps additional body organs) is maintained and which is not designed to provide the host with a body that can be used to explore the world through locomotion and direct physical manipulation. Such a neuroprosthesis might instead allow its host's mind to inhabit, move within, and manipulate some virtual environment through a virtual reality system that creates biocybernetic sensorimotor feedback loops, even though such a host's neuroprosthetic shell (and thus its body) may be immobile within the primary physical world.[51]

e. Reverse cyborg

A 'reverse cyborg' is not truly a cyborg; it is a human being who has undergone a reversed process of cyborgization in which most of the person's body is maintained intact while critical components of the brain that are needed to preserve the individual's personal identity are replaced with artificial biocybernetic components that are capable of regulating the work of body organs and perhaps even replicating the person's patterns of social behavior and interaction by receiving and processing sense data and generating appropriate motor output.

Due to its use of similar biocybernetic technologies, it might superficially appear to non-specialists as though the process of reverse cyborgization is similar to that of creating conventional types of cyborgs. However, while the ethical and legal questions connected with the creation of regular full or partial cyborgs are already quite serious, the questions associated with the creation of reverse cyborgs are even more grave: an individual expecting to undergo a surgical procedure and awaken with newly augmented capacities

[50] See Gladden, "Cybershells, Shapeshifting, and Neuroprosthetics" (2015).

[51] Such an arrangement resembles the 'brain in a vat' scenario discussed by Harman and Putnam and many others since within the field of philosophy of mind, building on the thought experiment involving an 'evil demon' formulated by Descartes in his *Meditations on First Philosophy* (1641). See Harman, *Thought* (1973), p. 5, and Putnam, *Reason, Truth and History* (1981).

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might instead have his or her brain destroyed and the remaining portion of his or her body artificially maintained and controlled by the operators of its neuroprosthetic interface as a sort of biological 'puppet' or 'zombie.'[52] From an ethical and legal perspective, intentionally creating such a being would appear to be highly illicit.

2. The Host as Avatar: Shaping Others' Perceptions of the Host

Some neuroprostheses are designed primarily to control, shape, or mediate the perceptions of a host's form and actions that other intelligent agents receive within a virtual environment. In other words, such neuroprostheses create an 'avatar' that constitutes or determines the host's body as it exists within some secondary physical world.

Even when the virtual body is designed to mimic as closely as possible its host's experience of his or her natural biological body, it actually provides its host with an anisomorphic body in the secondary physical world whose apparent size, shape, and construction do not correspond to the system's actual physical size, shape, and construction (comprising, for example, a set of electrons stored in the transistors of a RAM module and not a collection of biological cells) within the primary physical world.[53]

a. Cyberdouble

It is possible for a host's neuroprosthetically facilitated avatar to duplicate the host's actual physical appearance, features, and expressions in a way that is as authentic as possible, given the constraints of the virtual environment – thereby creating a virtual 'cyberdouble' of the host's body.

b. Cybermorph

Alternatively, a neuroprosthetically facilitated avatar may present to other inhabitants of a virtual environment an appearance that does not replicate its owner's actual physical appearance; such an avatar may be radically non-human in nature (e.g., appearing as a robotic spider or a floating ball of light), and inhabitants of the virtual environment may or may not be able to identify the avatar with its physical human owner.[54]

[52] The potential for such misuse of technologies for cybernetic augmentation is discussed in Gladden, *The Handbook of Information Security for Advanced Neuroprosthetics* (2015), pp. 98, 220.

[53] For a discussion of psychological, social, and political questions relating to repetitive long-term inhabitation of virtual worlds through a digital avatar, see, e.g., Castronova, "Theory of the Avatar" (2003).

[54] The extent to which a human being can make use of the (virtual) sensory and motor components and processes of a radically non-human avatar is limited by the adaptability of the individual's body schema. See Gladden, "Cybershells, Shapeshifting, and Neuroprosthetics" (2015).

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B. Embedding: Inhabitation of an External Environment

A neuroprosthetic device may significantly alter the way in which its host senses, controls, and otherwise experiences the environment surrounding the host's body. For example, a neuroprosthesis may extend the region of space within which environmental objects and phenomena can be detected and manipulated; increase or decrease those aspects of the environment that can be sensed and manipulated; reduce the capacity of other agents or forces within the environment to detect or affect the host; increase or decrease the host's ability to understand the structures and dynamics of the environment; and increase or decrease the host's social, psychological, or physical dependence on elements within the environment. The difference between transforming the way in which a device's host experiences the primary physical world (i.e., the 'real world') and providing the host with the experience of a secondary physical world (i.e., a 'virtual world') can be understood as the difference between exposing the host to augmented reality and immersing him or her in a virtual reality.

1. The World Viewed Through Augmented Reality

A neuroprosthetic device may employ augmented reality to provide its host with information that is not available through the host's natural biological sense organs or cognitive processes.[55]

a. Overlaid information

One possibility is for a neuroprosthesis to 'overlay' fabricated sense data that conveys specialized information atop the natural sense data that the device's host is receiving from his or her body or the environment. For example, a retinal prosthesis might double as a clock by periodically displaying the time as a set of numerals hovering within its host's field of vision, or it might highlight streets and buildings to help the host navigate to a desired destination. An auditory prosthesis might periodically produce audible information about its host's blood glucose level or live transmission of a radio station's broadcast that the host can hear atop the natural sounds produced by the environment.

b. Refracted reality

Another possibility is for a neuroprosthetic device to temporarily or permanently present its host with specialized information that replaces rather than overlays the kind of sense data that would naturally be produced by the host's biological sense organs. For example, consider a retinal prosthesis

[55] Regarding the potential use of neuroprosthetic implants to provide an augmented reality experience, see Koops & Leenes (2012); Sandor et al. (2015), pp. 5-6; and Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016).

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which – when activated – replaces its host's natural perception of visible light with infrared vision that only presents photons of infrared wavelengths that have been detected within the environment. Such a form of augmented reality can be understood as providing its user with a 'refracted' view of the world; it is as though the real world were being viewed through a particular type of filter or lens that both enhances and distorts. This is considered a form of augmented reality rather than virtual reality, because the world perceived by a device's host is isomorphic with the primary physical world; the device does not present a fabricated environment but a new way of experiencing the primary physical world.

2. Occupancy of a Virtual World

A neuroprosthesis may allow its host to inhabit a secondary physical world (or 'virtual world') by generating sense data that depicts the contents of the world and detecting motor instructions produced by the host's brain or spinal word which allow the host to manipulate the contents of the world.

a. Degree of immersion

Neuroprosthetic devices can be distinguished by the extent to which they immerse their hosts in a virtual environment.

I. Maximal immersion

In the strictest sense of the phrase, there is no such thing as a 'totally immersive' virtual reality system that can fully plunge its user into a virtual world, because the brain itself contains components that are sensitive to phenomena present within the primary physical world and whose functioning most likely cannot be wholly replaced or overridden by a neuroprosthesis. Even if a neuroprosthetic device were capable of completely blocking the sense data that a host's eyes, ears, nose, tongue, and skin normally receive from the primary physical environment and replacing them with fabricated sense data depicting a virtual environment,[56] the host's illusion of being present within that virtual environment would not be perfect or complete. For example, the virtual visual, auditory, and tactile data received by the host in a particular moment might give the impression that he or she is running

[56] It has been estimated that in principle, a virtual reality system would be capable of providing its user with a suite of visual, auditory, olfactory, gustatory, and tactile sense data whose quality equals that of sense data generated by the primary physical world, if the system were capable of presenting either roughly 200 Gbps of raw sense data to the host's natural biological sense organs (such as the retina, hair cells in the ear, and taste buds) through their external stimulation or roughly 250 Mbps of already-processed sense data in the form of direct electrochemical stimulation of the nerves (such as the optic and cochlear nerves) that carry such data to the brain or of the relevant brain regions themselves. See Berner, *Management in 20XX: What Will Be Important in the Future – A Holistic View* (2004), pp. 37-38, 45-47.

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along a beach; but if within the primary physical world the host's body were actually lying motionless in a hospital bed, sense data relating to the senses of proprioception and balance would 'tell' the host that his or her body were in fact not moving at all.[57] A sufficiently well-trained host would notice such discrepancies, and they would diminish the experienced degree of immersion in the virtual world.

Even if a highly sophisticated future neuroprosthesis were somehow capable of providing 100% of the sense data experienced by its host, it could still not eliminate the reality that the host's brain exists within the primary physical world – not a virtual environment – and as such, the brain is subject to environmental phenomena present within the primary physical world like heat, electromagnetic radiation, acceleration, and the introduction of chemical substances into the brain that may directly affect the brain's functioning and create for a device's host experiences that are inconsistent with the characteristics of the virtual environment that is being fabricated by the neuroprosthesis.[58]

In ordinary everyday conversation, it may be convenient to speak of some neuroprosthesis as providing its host with 'full' immersion in a virtual world; however, the word 'full' should not be understood literally: it would be more appropriately taken to mean that such a neuroprosthesis immerses its host in a virtual world "to the fullest extent possible." It is thus more correct to speak of such a device as offering its host 'maximal' immersion in the virtual environment of a secondary physical world.

II. Partial immersion

A neuroprosthetic system creates 'partial immersion' if it provides its host with an experience of inhabiting a virtual environment that is less complete than that experienced with maximal immersion. Examples would include artificial eyes which, when activated, present their user with the visual experience of existing and moving within some virtual world – but which do not

[57] Regarding varying forms of 'cybersickness' that may be experienced by users of virtual reality systems, see Polcar & Horejsi, "Knowledge Acquisition and Cyber Sickness: A Comparison of VR Devices in Virtual Tours" (2013), and Davis et al., "A systematic review of cybersickness" (2014). Some forms of cybersickness may be generated or exacerbated when a device's host receives dissonant sense data through different sense modalities, some of which may be presenting authentic sense data from the primary physical world and others fabricated sense data from a virtual world.

[58] Such mechanisms of direct action upon the brain would not include phenomena such as the microwave auditory effect, which appears to act upon components of the ear rather than on the brain itself. See, e.g., Lin, "Hearing microwaves: The microwave auditory phenomenon" (2001).

affect the host's sense of hearing, which continues to present auditory sense data from the primary physical world.[59]

b. Period of immersion

Neuroprosthetic devices that allow their hosts to inhabit a virtual environment may differ by typically immersing their hosts for varying periods of time.

I. Temporary immersion

A neuroprosthetic device may provide its host with periodic and temporary immersion in a virtual environment. For example, institutional VR systems might be accessible to an organization's employees during designated working hours but inaccessible at other times, and VR gaming systems may be used for those relatively short and sporadic stretches during which a user can find time to play.

For a neuroprosthesis that periodically immerses its host in a virtual environment for a very brief period of time, less attention will need to be given by the device's designers and operators to the potential psychological, physical, or social effects that may result from inhabiting that virtual environment for an extended period of time – however, greater attention will need to be paid to any impacts that affect the host when he or she transitions into or out of the virtual environment, since those transitional effects may be experienced a large number of times and in close succession. In particular, any cumulative impacts produced by entering and existing the virtual environment must be carefully identified and studied.

II. Long-term immersion

A neuroprosthesis may provide its host with long-term or potentially even permanent immersion in a virtual environment. This might be the case, for example, with individuals whose physical bodies have been so severely injured that they can only be kept alive within a large, complex, immobile life-support system that uses a neuroprosthetic interface to allow a patient who can no longer move or sense the primary physical world through his or her natural physical organs to explore virtual environments and interact with other human beings or non-human intelligent agents within them.[60]

In the case of a neuroprosthesis that immerses its host in a virtual environment for an extended (or even indefinite) period of time, the device's designers and operators will be obliged to pay close attention to the potential

[59] Regarding the effects of varying degrees of immersion in virtual reality environments, see Cummings & Bailenson, "How immersive is enough? A meta-analysis of the effect of immersive technology on user presence" (2016).

[60] The ramifications of long-term immersion in virtual reality environments in discussed, e.g., in Heim (1993); Koltko-Rivera (2005); and Bainbridge (2011).

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psychological, physical, or social effects that may result from long-term inhabitation of that virtual environment. It will also be necessary to study any impacts that affect the host when he or she transitions into or out of the virtual environment, as the rarity of such transitions may leave the host's mind and body ill-prepared for their effects. However, the cumulative impacts created by repeated transitions into and out of the virtual environment will be of less significance, as hosts are unlikely to encounter them.

c. Cognizance of immersion

Neuroprostheses may differ in the extent to which their hosts are aware of the fact that their devices are immersing them in a virtual environment.

i. Recognized immersion

Many neuroprosthetic devices that immerse their hosts in a virtual environment do so in such a way that a host is consciously aware of when he or she is entering, leaving, or present within the virtual environment. It will be especially easy for hosts to gain and possess such knowledge when the virtual environment differs noticeably from the primary physical world and hosts periodically transition in and out of the virtual environment, rather than remaining within it permanently.

ii. Unrecognized immersion

Some neuroprosthetic devices might conceivably immerse their hosts in a virtual environment in such a way that a host is not consciously aware of inhabiting a virtual environment when he or she is immersed in it.[61]

It may be difficult for a host to recognize that he or she is in a virtual environment if, for example: a) the virtual environment strongly resembles the primary physical world with which the host was previously familiar; b) the transition into the virtual environment has occurred while the host was asleep or otherwise unable to consciously observe the transition; c) the neuroprosthesis disrupts the host's memory functions that would allow the host to remember differences that have been experienced between the primary and secondary physical worlds;[62] or d) the host remains permanently immersed in the virtual environment, thereby being deprived of the possibility

[61] The fact that a host may not be consciously aware of the fact that he or she is immersed in a virtual environment is consistent with the fact – discussed earlier – that no VR system can create a state of 'full immersion' that severs the host from the influences of the primary physical world. As noted earlier, a host's physical brain will always be subject to the effects of phenomena such as cosmic rays, heat, or electromagnetic fields that exist in the primary physical world; however it is possible that such phenomena will not generate or influence sensory experiences in such a way that the host will become consciously aware of the phenomena's existence.

[62] The possible development of neuroprostheses that may alter or disrupt the memories of their human hosts is discussed in Gladden, *Sapient Circuits and Digitalized Flesh* (2016), and Gladden,

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of noticing transitions into and out of the virtual environment and recognizing discrepancies between the virtual environment and primary physical world.

IV. The Neuroprosthesis as a Regulator of Agency

Neuroprostheses interact with the agency possessed and exercised by their human hosts in a range of ways. 'Weak' notions of agency define an agent as any entity that displays the externally observable characteristics of autonomy, reactivity, proactivity, and the ability for social interaction; 'strong' notions of agency insist that an agent also possess internal mental phenomena such as beliefs and desires (which, when joined, can constitute intentions).[63] The human beings who serve as hosts to neuroprosthetic devices are not only agents in the weak sense but also in the strong sense: as human beings, we experience our own beliefs, desires, and intentions, and we realize that any condition (such as illness or injury) that destroys our ability to experience beliefs, desires, and intentions would also eliminate our capacity to act as agents within the world.

Neuroprosthetic devices may themselves possess and exercise agency in the weak sense; the question of whether future neuroprostheses endowed with sufficiently sophisticated artificial intelligence might someday also possess agency in the strong sense is a contested issue. Below we consider neuroprostheses that manifest and interact with agency in different ways.

A. The Neuroprosthesis as Agent

A neuroprosthesis may or may not possess and exercise its own agency.

1. Neuroprostheses Possessing Agency

A neuroprosthesis may possesses and exercise its own autonomous agency within the context of its host-device system.[64] The agency of the neuropros-

"Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016). Such devices might potentially build on experimental technologies for the artificial generation, alteration, or deletion of memories currently being tested in mice. See, e.g., Han et al. (2009); Josselyn, "Continuing the Search for the Engram: Examining the Mechanism of Fear Memories" (2010); and Ramirez et al. (2013).

[63] For these definitions of agency, see Wooldridge & Jennings, "Intelligent agents: Theory and practice" (1995), and Lind, "Issues in agent-oriented software engineering" (2001). For more on the relationship of beliefs, desires, and intentions, see Calverley, "Imagining a non-biological machine as a legal person" (2008).

[64] For computerized devices such as neuroprostheses, autonomy can be understood as the state of being "capable of operating in the real-world environment without any form of external control for extended periods of time." See Bekey, *Autonomous Robots: From Biological Inspiration to*

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thetic device may be generated and governed by, for example, a software program controlling the device or by the functioning of a physical neural network that controls the neuroprosthesis.

2. Neuroprostheses Lacking Their Own Agency

Some neuroprosthetic devices do not possess their own agency. Examples might be found in host-device systems in which only the human host possesses and exercises agency and the implanted device – while integrated into its host's neural circuitry – is passive in function.[65]

B. The Neuroprosthesis as Instrument of External Agency

While lacking its own autonomous agency, a neuroprosthetic device might act as a tool that extends the agency of some external agent into the organism of the device's host. An example would include a neuroprosthesis that is remotely controlled by medical personnel who use the device as a telepresence instrument to provide telemedicine services to the device's human host, who lives in a remote location where physicians are not available to administer medical services in person.[66] A neuroprosthesis that has been remotely hijacked by a hacker and whose operation is now being controlled by that adversary would be another example of a neuroprosthetic device functioning as an instrument of an external agent.[67]

C. The Neuroprosthesis as Modulator of a Host's Human Agency

Neuroprosthetic devices demonstrate a range of impacts on the autonomy and agency of their human hosts. While some devices may have no direct impact on their host's agency, other devices may enhance, impair, or eradicate their host's ability to possess and manifest agency.

1. Agency-realizing Neuroprostheses

A neuroprosthetic device may possess agency that is ultimately exercised not in the form of autonomy and independent action but through a purposefully designed subordination to the agency of the device's host and his or her

Implementation and Control (2005), p. 1.

[65] The existence of pieces of implantable information and communications technology (ICT) such as neuroprostheses that are passive in their functionality is discussed in Roosendaal, "Implants and Human Rights, in Particular Bodily Integrity" (2012), and Gladden, *The Handbook of Information Security for Advanced Neuroprosthetics* (2015).

[66] For the remote administration of implantable medical devices as a means of administering telemedicine, see Gasson (2012) and Gladden, "Managing the Ethical Dimensions of Brain-Computer Interfaces in eHealth" (2016).

[67] For such possibilities, see Denning et al., "Neurosecurity: Security and Privacy for Neural Devices" (2009); Krishnan, "From Psyops to Neurowar: What Are the Dangers?" (2014); and Gladden, *The Handbook of Information Security for Advanced Neuroprosthetics* (2015).

volitions; such a neuroprosthesis would exercise its agency by attempting to detect the volitions of its human host and faithfully implement and realize those volitions. Examples might include an artificially intelligent prosthetic robotic arm that replaces a natural biological arm that its host has lost due to injury and which employs its agency to detect motor instructions generated in its host's brain and move in such a way as to successfully enact the host's volitions.

2. Agency-extending Neuroprostheses

A neuroprosthesis might attempt to capture and preserve or replicate the natural agency that would have been exercised by its host, in order to manifest that agency in a remote location in which the host is not directly present or at a time when the host cannot directly exercise his or her normal agency (e.g., while the host is unconscious or asleep or after his or her death).

3. Agency-complementing Neuroprostheses

A neuroprosthetic device may possess agency which complements that of its human host and aids the host in his or her activities while ultimately maintaining independence as an agent and not being directly subject to the host's control. Such a device might employ a form of artificial intelligence to serve as an advisor, counsellor, companion, or friend to its human host.[68]

4. Agency-controlling Neuroprostheses

A neuroprosthetic device may possess some form of agency that it uses to directly or indirectly constrain or control its host's autonomous possession and exercise of agency. Such a neuroprosthesis might be employed as a means of medical treatment, surveillance, punishment, training, or workplace supervision.[69]

5. Agency-enhancing Neuroprostheses

A neuroprosthesis may enhance its host's ability to possess and exercise agency – perhaps by removing or inhibiting some obstacle that normally disrupts the host's agency. For example, some users of deep brain stimulation

[68] For discussions of robotic devices or artificially intelligent systems serving as colleagues and assistants to human workers, see, e.g., Ablett et al., "A Robotic Colleague for Facilitating Collaborative Software Development" (2006); Vänni and Korpela, "Role of Social Robotics in Supporting Employees and Advancing Productivity" (2015); and Gladden, "Leveraging the Cross-Cultural Capacities of Artificial Agents as Leaders of Human Virtual Teams" (2014). For robots that serve as charismatic leaders (and perhaps even spiritual guides) for human beings, see Gladden, "The Social Robot as 'Charismatic Leader': A Phenomenology of Human Submission to Nonhuman Power" (2014).

[69] For such possibilities, see Barfield, *Cyber-Humans: Our Future with Machines* (2015), p. 111, and Gladden, *The Handbook of Information Security for Advanced Neuroprosthetics* (2015).

devices employed to treat Parkinson's disease and other conditions have reported that their sense of autonomy and ability to exercise personal agency have been enhanced by use of such devices.[70]

6. Agency-impairing Neuroprostheses

A neuroprosthesis may temporarily or permanently impair its host's possession and exercise of agency without completely destroying that agency. Such devices might include an anesthetic neuroprosthesis that periodically induces a state of unconsciousness in its host or an emergency life support system that preserves a human brain intact but deprives it of the sensory and motor capacities that allow it to manifest its agency.[71]

7. Agency-eradicating Neuroprostheses

A neuroprosthetic device may permanently eradicate the ability of its host to possess and exercise agency within the world. This may occur if the presence or use of the device results in the death of its host's biological organism or if it damages or destroys neurons and brain structures to such an extent that the host – while still being maintained in a living state – can no longer exercise his or her natural agency.

D. The Neuroprosthesis as Hive Mind Infrastructure

A neuroprosthesis may link the mind of its human host with external intelligences (such as the minds of other neuroprosthetically augmented human beings or artificial intelligences) in such a way that the mind of the human host and the external agents form a sort of collective entity or 'hive mind.' The level at which and extent to which the cognitive processes of the hive mind's members are connected may vary.[72]

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[70] See the discussion of such issues in Kraemer, "Me, Myself and My Brain Implant: Deep Brain Stimulation Raises Questions of Personal Authenticity and Alienation" (2011); Van den Berg, "Pieces of Me: On Identity and Information and Communications Technology Implants" (2012); McGee (2008); and Gladden, *Sapient Circuits and Digitalized Flesh* (2016).

[71] Such possibilities are discussed, e.g., in Gladden, *The Handbook of Information Security for Advanced Neuroprosthetics* (2015), and Gladden, "Neural Implants as Gateways to Digital-Physical Ecosystems and Posthuman Socioeconomic Interaction" (2016).

[72] The prospect of creating hive minds and neuroprosthetically facilitated collective intelligences is discussed, e.g., in McIntosh, "The Transhuman Security Dilemma" (2010); Roden, *Posthuman Life: Philosophy at the Edge of the Human* (2014), p. 39; and Gladden, "Utopias and Dystopias as Cybernetic Information Systems: Envisioning the Posthuman Neuropolity" (2015). For classifications of different kinds of potential hive minds, see Chapter 2, "Hive Mind," in Kelly, *Out of Control: The New Biology of Machines, Social Systems and the Economic World* (1994); Kelly, "A Taxonomy of Minds" (2007); Kelly, "The Landscape of Possible Intelligences" (2008); Yonck, "Toward a standard metric of machine intelligence" (2012); and Yampolskiy, "The Universe of Minds" (2014). For critical perspectives on the notion of hive minds, see, e.g., Maguire & McGee (1999); Bendle, "Teleportation, cyborgs and the posthuman ideology" (2002); and Heylighen, "The Global Brain as a New Utopia" (2002).

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1. The Hive Mind as Sensorimotor Network

It is possible for a neuroprosthesis to link the mind of its host with other intelligent agents to form a collection of intelligences in which the host maintains his or her sense of personal identity and autonomy and experiences the thoughts and volitions of the other intelligences as phenomena whose origins are external to the host's own mind and which are perceived through the host's sense organs. The host's mind interacts with the hive mind's other member-intelligences, while still recognizing them as independent entities that are part of the external environment and not part of the host's own mind.

2. The Hive Mind as Facilitator of Internal Dialogue

A neuroprosthetic device may link its host's mind to external intelligences in such a way that the host becomes consciously aware of and experiences those intelligences' volitions and agency as 'voices' speaking to the host from within his or her own mind. Instead of experiencing the internal monologue that is a natural part of human mental life, the host would experience an internal dialogue in which his or her own inner voice converses with the voices of other members of the hive mind.

3. The Hive Mind as Unitary Collective Intelligence

A neuroprosthesis might conceivably link its host's mind to the cognitive processes of one or more other intelligent agents (either those of the device itself or of external artificial or human agents) in such a way that the host's mind ceases to directly experience its own volition or personal identity as such – and does not experience the cognitive processes of external agents as belonging to those agents – but instead shares with the external agents the experience of jointly creating a single mind and will. Over time, such a host may experience a loss of individuality and sense of self by becoming immersed in the collective hive mind whose thoughts and actions are determined jointly by the cognitive activity of its members.[73] Depending on the nature of the device and its long-term effects on the neural structures and cognitive processes of its human host, it may or may not be possible to restore the host's mind to its full experience of independent agency simply by terminating the device's operation.

Conclusion

In earlier chapters we considered an ontology of the neuroprosthesis as a computing device and as a biocybernetic instrument that becomes integrated

[73] A related network topology would be that of a 'quasi-hive-mind' or 'pseudo-hive-mind,' in which the host *experiences* the hive mind as though it were being created through the joint action of all its participants, while in reality the contents of the hive mind's cognitive processes are largely determined or controlled by the actions of one of its members or an external system.

into the neural circuitry of a human organism in order to participate in processes of sensation, cognition, and motor action. In this chapter, we completed our classification and analysis of neurocybernetic technologies by developing an ontology of the neuroprosthesis as a means for the 'cyborgization' of human beings that shapes how individuals possessing such devices experience posthumanized digital-physical worlds. The ontology addressed four roles that a neuroprosthesis may play in such processes. First, a neuroprosthesis can serve as a means of human augmentation by transforming the cognitive and physical capacities possessed by its host. Second, it can determine the contents of information generated or utilized by its human host. Third, a neuroprosthesis can affect the manner in which its host inhabits a digital-physical body and external environment. And finally, a neuroprosthesis can regulate the autonomous agency possessed and experienced by its host.

It is hoped that the development of such an ontology will enable researchers to better understand the psychological, social, and ethical implications of such technologies and will allow the architects of neuroprosthetic systems – and of the digital-physical ecosystems within which they are situated – to design and manage such systems in a way that safeguards and advances the well-being of devices' human hosts while maximizing the security, vibrancy, and efficiency of the digital-physical ecosystems within which they are situated.

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ISBN 978-1-944373-07-8 (print edition) and 978-1-944373-08-5 (ebook).

References

Ablett, Ruth, Shelly Park, Ehud Sharlin, Jörg Denzinger, and Frank Maurer. "A Robotic Colleague for Facilitating Collaborative Software Development." *Proceedings of Computer Supported Cooperative Work (CSCW 2006)*. ACM, 2006.

Adaptive Networks: Theory, Models and Applications, edited by Thilo Gross and Hiroki Sayama. Springer Berlin Heidelberg, 2009.

Advances in Neuromorphic Memristor Science and Applications, edited by Robert Kozma, Robinson E. Pino, and Giovanni E. Pazienza. Dordrecht: Springer Science+Business Media, 2012.

Ahlemann, Frederik, Eric Stettiner, Marcus Messerschmidt, Christine Legner, Kunal Mohan, and Daniel Schäfczuk. "People, adoption and introduction of EAM." In *Strategic Enterprise Architecture Management*, pp. 229-263. Springer Berlin Heidelberg, 2012.

Aier, Stephan. "The Role of Organizational Culture for Grounding, Management, Guidance and Effectiveness of Enterprise Architecture Principles." *Information Systems and E-Business Management* 12, no. 1 (2014): 43-70.

Alumur, Sibel, and Bahar Y. Kara. "Network hub location problems: The state of the art." *European journal of operational research* 190, no. 1 (2008): 1-21.

Amputation, Prosthetic Use, and Phantom Limb Pain: An Interdisciplinary Perspective, edited by Craig Murray. New York: Springer Science+Business Media, 2010.

Andersen, Peter A., and Janis F. Andersen. "Measures of Perceived Nonverbal Immediacy." In *The Sourcebook of Nonverbal Measures: Going Beyond Words*, edited by Valerie Manusov. Mahwah, NJ: Lawrence Erlbaum Associates, Inc., 2005.

Anderson, Walter Truett. "Augmentation, symbiosis, transcendence: technology and the future(s) of human identity." *Futures* 35, no. 5 (2003): 535-46.

Anderson, Michael L. "Embodied cognition: A field guide." *Artificial intelligence* 149, no. 1 (2003): 91-130.

Andrew, Alex M. "The decade of the brain: further thoughts." *Kybernetes* 26, no. 3 (1997): 255-264.

Ankarali, Z.E., Q.H. Abbasi, A.F. Demir, E. Serpedin, K. Qaraqe, and H. Arslan. "A Comparative Review on the Wireless Implantable Medical Devices Privacy and Security." In *2014 EAI 4th International Conference on Wireless Mobile Communication and Healthcare (Mobihealth)*, 246-49, 2014. doi:10.1109/MOBIHEALTH.2014.7015957.

ANSI/IEEE 1471-2000, IEEE Recommended Practice for Architectural Description for Software-Intensive Systems. IEEE Computer Society, 2000.

ArchiMate® 2.1 Specification. Berkshire: The Open Group, 2013.

Ariely, D., and G.S. Berns. "Neuromarketing: The Hope and Hype of Neuroimaging in Business." *Nature Reviews Neuroscience* 11, no. 4 (2010): 284-92.

Austerberry, David. *Digital Asset Management*. Second edition. Burlington, MA: Focal Press, 2013.

Ayaz, Hasan, Patricia A. Shewokis, Scott Bunce, Maria Schultheis, and Banu Onaral. "Assessment of Cognitive Neural Correlates for a Functional Near Infrared-Based Brain Computer Interface System." In *Foundations of Augmented Cognition. Neuroergonomics and Operational Neuroscience*, edited by Dylan D. Schmorrow, Ivy V. Estabrooke, and Marc Grootjen, 699-708. Lecture Notes in Computer Science 5638. Springer Berlin Heidelberg, 2009.

Baars, Bernard J. *In the Theater of Consciousness.* New York, NY: Oxford University Press, 1997.

Baddeley, Alan. "The episodic buffer: a new component of working memory?" *Trends in cognitive sciences* 4, no. 11 (2000): 417-23.

Baddeley, Alan. "Working memory: theories, models, and controversies." *Annual review of psychology* 63 (2012): 1-29.

Bainbridge, William Sims. *The Virtual Future*. London: Springer, 2011.

Băjenescu, Titu-Marius, and Marius I. Bâzu. *Reliability of Electronic Components: A Practical Guide to Electronic Systems Manufacturing*. Springer Berlin Heidelberg, 1999.

Baranyi, Péter, Adam Csapo, and Gyula Sallai. "Synergies Between CogInfoCom and Other Fields." In *Cognitive Infocommunications (CogInfoCom).* Springer International Publishing, 2015.

Barfield, Woodrow. *Cyber-Humans: Our Future with Machines.* Springer Science+Business Media, 2015.

Barile, S., J. Pels, F. Polese, and M. Saviano. "An Introduction to the Viable Systems Approach and Its Contribution to Marketing." *Journal of Business Market Management* 5(2) (2012): 54-78.

Bean, Sally. "Re-Thinking Enterprise Architecture Using Systems and Complexity Approaches." *Journal of Enterprise Architecture* 6, no. 4 (2010).

Beer, Stafford. *Brain of the Firm*. Second edition. New York: John Wiley, 1981.

Bekey, G.A. *Autonomous Robots: From Biological Inspiration to Implementation and Control*. Cambridge, MA: MIT Press, 2005.

Bendle, Mervyn F. "Teleportation, cyborgs and the posthuman ideology." *Social Semiotics* 12, no. 1 (2002): 45-62.

Bergey, John, Stephen Blanchette, Jr., Paul Clements, Mike Gagliardi, John Klein, Rob Wojcik, and Bill Wood. "U.S. Army Workshop on Exploring Enterprise, System of Systems, System, and Software Architectures." Technical Report CMU/SEI-2009-TR-008 / ESC-TR-2009-008. Hanscom AFB, MA: Software Engineering Institute, 2009.

Berner, Georg. *Management in 20XX: What Will Be Important in the Future – A Holistic View*. Erlangen: Publicis Corporate Publishing, 2004.

Bhunia, Swarup, Abhishek Basak, Seetharam Narasimhan, and Maryam Sadat Hashemian. "Ultralow Power and Robust On-Chip Digital Signal Processing for Closed-Loop Neuro-Prosthesis." In *Implantable Bioelectronics: Devices, Materials, and Applications*, edited by Evgeny Katz. Weinheim: Wiley-VCH, 2014.

Birnbacher, Dieter. "Posthumanity, Transhumanism and Human Nature." In *Medical Enhancement and Posthumanity*, edited by Bert Gordijn and Ruth Chadwick, pp. 95-106. The International Library of Ethics, Law and Technology 2. Springer Netherlands, 2008.

"An Ontology of Neuroprostheses as Instruments of 'Cyborgization': Portals to the Experience of Posthumanized Digital-Physical Worlds," Chapter Three in Gladden, Matthew E., Neuroprosthetic Supersystems Architecture, pp. 113-45. Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-07-8 (print edition) and 978-1-944373-08-5 (ebook).

Bischoff, Stefan, Stephan Aier, and Robert Winter. "Use It or Lose It? The Role of Pressure for Use and Utility of Enterprise Architecture Artifacts." In *2014 IEEE 16th Conference on Business Informatics*, vol. 2, pp. 133-140. IEEE, 2014.

Black, Michael J., Elie Bienenstock, John P. Donoghue, Mijail Serruya, Wei Wu, and Yun Gao. "Connecting brains with machines: the neural control of 2D cursor movement." In *Proceedings of the 1st International IEEE/EMBS Conference on Neural Engineering*, pp. 580-83, 2003.

Blank, S. Catrin, Sophie K. Scott, Kevin Murphy, Elizabeth Warburton, and Richard JS Wise. "Speech production: Wernicke, Broca and beyond." *Brain* 125, no. 8 (2002): 1829-38.

Bogue, Robert. "Brain-Computer Interfaces: Control by Thought." *Industrial Robot: An International Journal* 37, no. 2 (2010): 126-32.

Boly, Melanie, Anil K. Seth, Melanie Wilke, Paul Ingmundson, Bernard Baars, Steven Laureys, David B. Edelman, and Naotsugu Tsuchiya. "Consciousness in humans and non-human animals: recent advances and future directions." *Frontiers in Psychology* 4 (2013).

Bonaci, T., R. Calo, and H. Chizeck. "App Stores for the Brain." *IEEE Technology and Society Magazine,* 1932-4529/15 (2015): 32-39.

Borkar, Shekhar. "Designing reliable systems from unreliable components: the challenges of transistor variability and degradation." *Micro, IEEE* 25, no. 6 (2005): 10-16.

Bostrom, Nick. "Human Genetic Enhancements: A Transhumanist Perspective." In *Arguing About Bioethics*, edited by Stephen Holland, pp. 105-15. New York: Routledge, 2012.

Bostrom, Nick, and Anders Sandberg. "Cognitive Enhancement: Methods, Ethics, Regulatory Challenges." *Science and Engineering Ethics* 15, no. 3 (2009): 311-41.

Boucharas, Vasilis, Marlies van Steenbergen, Slinger Jansen, and Sjaak Brinkkemper. "The Contribution of Enterprise Architecture to the Achievement of Organizational Goals: A Review of the Evidence." In *Trends in Enterprise Architecture Research*, 1-15. Springer, 2010.

Braddon-Mitchell, David, and John Fitzpatrick. "Explanation and the Language of Thought." *Synthese* 83, no. 1 (April 1, 1990): 3-29.

Bradford, David L., and W. Warner Burke. *Reinventing Organization Development: New Approaches to Change in Organizations*. John Wiley & Sons, 2005.

Brain-Computer Interfaces: Principles and Practice, edited by Jonathan R. Wolpaw and Elizabeth Winter Wolpaw. New York: Oxford University Press, 2012.

Brandt, Thomas. *Vertigo: Its Multisensory Syndromes*. Springer Verlag London, 2003.

Breazeal, Cynthia. "Toward sociable robots." *Robotics and Autonomous Systems* 42 (2003): 167-75.

"Bridging the Bio-Electronic Divide." Defense Advanced Research Projects Agency, January 19, 2016. http://www.darpa.mil/news-events/2015-01-19. Accessed May 6, 2016.

Brunner, Peter, and Gerwin Schalk. "Brain-Computer Interaction." In *Foundations of Augmented Cognition. Neuroergonomics and Operational Neuroscience*, edited by Dylan D. Schmorrow, Ivy V. Estabrooke, and Marc Grootjen, 719-23. Lecture Notes in Computer Science 5638. Springer Berlin Heidelberg, 2009.

Brunner, P., L. Bianchi, C. Guger, F. Cincotti, and G. Schalk. "Current Trends in Hardware and Software for Brain-Computer Interfaces (BCIs)." *Journal of Neural Engineering* 8, no. 2 (2011): 25001.

Bublitz, J.C. "If Man's True Palace Is His Mind, What Is Its Adequate Protection? On a Right to Mental Self-Determination and Limits of Interventions into Other Minds." In *Technologies on the Stand: Legal and Ethical Questions in Neuroscience and Robotics*, edited by B. Van Den Berg and L. Klaming. Nijmegen: Wolf Legal Publishers, 2011.

"An Ontology of Neuroprostheses as Instruments of 'Cyborgization': Portals to the Experience of Posthumanized Digital-Physical Worlds," Chapter Three in Gladden, Matthew E., Neuroprosthetic Supersystems Architecture, pp. 113-45. Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-07-8 (print edition) and 978-1-944373-08-5 (ebook).

Buckl, Sabine, Christian M. Schweda, and Florian Matthes. "A Situated Approach to Enterprise Architecture Management." In *2010 IEEE International Conference on Systems, Man and Cybernetics*, 587-92. IEEE, 2010.

Buckl, Sabine, Florian Matthes, and Christian M. Schweda. "A Viable System Perspective on Enterprise Architecture Management." In *IEEE International Conference on Systems, Man and Cybernetics, 2009. SMC 2009*, 1483-88. IEEE, 2009.

Butler, Jesse. *Rethinking Introspection*. Palgrave Macmillan UK, 2013.

C4ISR Architecture Framework Version 2.0. C4ISR Architecture Working Group (AWG), US Department of Defense, December 18, 1997. http://www.afcea.org/education/courses/archfwk2.pdf. Accessed December 4, 2016.

Cadle, James, Debra Paul, and Paul Turner. *Business Analysis Techniques: 72 Essential Tools for Success.* Swindon: British Informatics Society Limited, 2010.

Caetano, Artur, António Rito Silva, and José Tribolet. "A Role-Based Enterprise Architecture Framework." In *Proceedings of the 2009 ACM Symposium on Applied Computing*, pp. 253-58. ACM, 2009.

Cahill, Larry, and Michael T. Alkire. "Epinephrine enhancement of human memory consolidation: interaction with arousal at encoding." *Neurobiology of learning and memory* 79, no. 2 (2003): 194-98.

Callaghan, Vic. "Micro-Futures." Presentation at Creative-Science 2014, Shanghai, China, July 1, 2014.

Calverley, D.J. "Imagining a non-biological machine as a legal person." *AI & SOCIETY* 22, no. 4 (2008): 523-37.

Cameron, Oliver G. *Visceral Sensory Neuroscience: Interoception.* Oxford University Press, 2001.

Campbell, Lyle. *Historical Linguistics.* Third edition. The MIT Press, 2013.

Cane, Sheila, and Richard McCarthy. "Measuring the Impact of Enterprise Architecture." *Issues in Information Systems* 8, no. 2 (2007): 437-42.

Castronova, Edward. "Theory of the Avatar." CESifo Working Paper No. 863, February 2003. http://www.cesifo.de/pls/guestci/download/CESifo+Working+Papers+2003/CESifo+Working+Papers+February+2003+/cesifo_wp863.pdf. Accessed January 25, 2016.

Cervera-Paz, Francisco Javier, and M. J. Manrique. "Auditory Brainstem Implants: Past, Present and Future Prospects." In *Operative Neuromodulation*, edited by Damianos E. Sakas and Brian A. Simpson, 437-42. Acta Neurochirurgica Supplements 97/2. Springer Vienna, 2007.

Chafe, Chris, and Sile O'Modhrain. "Musical muscle memory and the haptic display of performance nuance." In *Proceedings of the 1996 International Computer Music Conference*, pp. 1-4. Stanford: Stanford University, 1996.

Chan, Yolande E., and Blaize Horner Reich. "IT alignment: what have we learned?" *Journal of Information technology* 22, no. 4 (2007): 297-315.

Chang, Chia-Ke, Yu-Jung Li, and Chih-Cheng Lu. "RFID applied in recognition and identification for dental prostheses." In *Computerized Healthcare (ICCH), 2012 International Conference on*, pp. 43-45. IEEE, 2012.

Christen, Markus, and Sabine Müller. "Current status and future challenges of deep brain stimulation in Switzerland." *Swiss Medical Weekly* (2012): 142:w13570. doi:10.4414/smw.2012.13570.

"Chronic Pain and Spinal Cord Stimulation (SCS): Frequently Asked Questions." Boston Scientific, 2013. http://www.pae-eu.eu/wp-content/uploads/2015/03/NM-135814-AA-INTL-Spectra-Backgrounder_Final.pdf. Accessed December 8, 2016.

Church, George M., Yuan Gao, and Sriram Kosuri. "Next-generation digital information storage in DNA." *Science* 337, no. 6102 (2012): 1628.

Clancy, Frank. "At Military's Behest, Darpa Uses Neuroscience to Harness Brain Power." *Neurology Today* 6, no. 2 (2006): 4-8.

Clark, S.S., and K. Fu. "Recent Results in Computer Security for Medical Devices." In *Wireless Mobile Communication and Healthcare*, edited by K.S. Nikita, J.C. Lin, D.I. Fotiadis, and M.-T. Arredondo Waldmeyer, pp. 111-18. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering 83. Springer Berlin Heidelberg, 2012.

Clark, Andy. "Systematicity, structured representations and cognitive architecture: A reply to Fodor and Pylyshyn." In *Connectionism and the Philosophy of Mind*, pp. 198-218. Springer Netherlands, 1991.

Clark, Andy. *Natural-born cyborgs: Minds, Technologies, and the Future of Human Intelligence*. Oxford: Oxford University Press, 2004.

Clarke, Arthur C. "Hazards of Prophecy: The Failure of Imagination." In *Profiles of the Future: An Inquiry into the Limits of the Possible,* revised edition. Harper & Row, New York, 1973.

Clausen, J. "Conceptual and Ethical Issues with Brain–hardware Interfaces." *Current Opinion in Psychiatry* 24, no. 6 (2011): 495-501.

Claussen, Jens Christian, and Ulrich G. Hofmann. "Sleep, Neuroengineering and Dynamics." *Cognitive Neurodynamics* 6, no. 3 (May 27, 2012): 211-14.

A Clinical Guide to Transcranial Magnetic Stimulation, edited by Paul E. Holtzheimer and William McDonald. New York: Oxford University Press, 2014.

Clowes, Robert W. "The Cognitive Integration of E-Memory." *Review of Philosophy and Psychology* 4, no. 1 (January 26, 2013): 107-33.

"Cochlear Implant Quick Facts." American Speech-Language-Hearing Association. http://www.asha.org/public/hearing/Cochlear-Implant-Quick-Facts/. Accessed December 8, 2016.

"Cochlear Implants." National Institute on Deafness and Other Communication Disorders (NIDCD), May 3, 2016. https://www.nidcd.nih.gov/health/cochlear-implants. Accessed December 8, 2016.

Coeckelbergh, Mark. "From Killer Machines to Doctrines and Swarms, or Why Ethics of Military Robotics Is Not (Necessarily) About Robots." *Philosophy & Technology* 24, no. 3 (2011): 269-78.

Cognitive Psychology. Second edition. Edited by Nick Braisby and Angus Gellatly. Oxford: Oxford University Press, 2012.

Coker, Christopher. "Biotechnology and War: The New Challenge." *Australian Army Journal* vol. II, no. 1 (2004): 125-40.

Collins, Allison, and Norm Schultz. "A review of ethics for competitive intelligence activities." *Competitive Intelligence Review* 7, no. 2 (1996): 56-66.

Coma Science: Clinical and Ethical Implications, edited by Steven Laureys, Nicholas D. Schiff, and Adrian M. Owen. New York: Elsevier, 2009.

Comai, Alessandro. "Global code of ethics and competitive intelligence purposes: an ethical perspective on competitors." *Journal of Competitive Intelligence and Management* 1, no. 3, 2003.

Comas and Disorders of Consciousness, edited by Caroline Schnakers and Steven Laureys. Springer-Verlag London, 2012.

"An Ontology of Neuroprostheses as Instruments of 'Cyborgization': Portals to the Experience of Posthumanized Digital-Physical Worlds," Chapter Three in Gladden, Matthew E., Neuroprosthetic Supersystems Architecture, pp. 113-45. Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-07-8 (print edition) and 978-1-944373-08-5 (ebook).

Communication in the Age of Virtual Reality, edited by Frank Biocca and Mark R. Levy. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers, 1995.

Computer Synthesized Speech Technologies: Tools for Aiding Impairment, edited by John Mullennix and Steven Stern. Hershey, PA: Medical Information Science Reference, 2010.

Conant, Roger C., and W. Ross Ashby. "Every Good Regulator of a System Must Be a Model of That System." *International journal of systems science* 1, no. 2 (1970): 89-97.

Content of Premarket Submissions for Management of Cybersecurity in Medical Devices: Guidance for Industry and Food and Drug Administration Staff. Silver Spring, MD: US Food and Drug Administration, 2014.

Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science, edited by William Sims Bainbridge. Dordrecht: Springer Science+Business Media, 2003.

Cornwall, Warren. "In Pursuit of the Perfect Power Suit." *Science* 350, issue 6258 (2015): 270-73.

Cory, Jr., Gerald A. "Language, Brain, and Neuron." In *Toward Consilience*, pp. 193-205. Springer US, 2000.

Cosgrove, G.R. "Session 6: Neuroscience, brain, and behavior V: Deep brain stimulation." Meeting of the President's Council on Bioethics. Washington, DC, June 24-25, 2004. https://bioethicsarchive.georgetown.edu/pcbe/transcripts/june04/session6.html. Accessed June 12, 2015.

Coughlin, Thomas M. *Digital Storage in Consumer Electronics: The Essential Guide*. Burlington, MA: Newnes, 2008.

Crane, Andrew. "In the company of spies: When competitive intelligence gathering becomes industrial espionage." *Business Horizons* 48, no. 3 (2005): 233-40.

Cummings, James J., and Jeremy N. Bailenson. "How immersive is enough? A meta-analysis of the effect of immersive technology on user presence." *Media Psychology* 19, no. 2 (2016): 272-309.

Curtis, H. *Biology*. Fourth edition. New York: Worth, 1983.

"Cybersecurity for Medical Devices and Hospital Networks: FDA Safety Communication." US Food and Drug Administration, June 13, 2013. http://www.fda.gov/MedicalDevices/Safety/AlertsandNotices/ucm356423.htm. Accessed May 3, 2016.

Cybersociety 2.0: Revisiting Computer-Mediated Communication and Community, edited by Steven G. Jones. Thousand Oaks: Sage Publications, 1998.

The Cyborg Experiments: The Extensions of the Body in the Media Age, edited by Joanna Zylinska. London: Continuum, 2002.

Cytowic, Richard E. *Synesthesia: A Union of the Senses.* Springer-Verlag New York, 1989.

Daft, Richard L. *Management*. Mason, OH: South-Western / Cengage Learning, 2011.

Daft, Richard L., Jonathan Murphy, and Hugh Willmott. *Organization Theory and Design.* Andover, Hampshire: Cengage Learning EMEA, 2010.

Daigle, K.R. "Manipulating the Mind: The Ethics of Cognitive Enhancement." Thesis, M.A. in Bioethics. Wake Forest University, 2010. https://wakespace.lib.wfu.edu/handle/10339/30407. Accessed May 8, 2016.

Dandamudi, Sivarama P. *Introduction to assembly language programming: from 8086 to Pentium processors*. Springer Science+Business Media New York, 1998.

Davies, Theresa Claire. *Audification of Ultrasound for Human Echolocation*. Dissertation, Ph.D. in Systems Design Engineering. Waterloo, Ontario: University of Waterloo, 2008.

Davis, Simon, Keith Nesbitt, and Eugene Nalivaiko. "A systematic review of cybersickness." In *Proceedings of the 2014 Conference on Interactive Entertainment*, pp. 1-9. ACM, 2014.

De Graaf, Maartje MA, and Somaya Ben Allouch. "Exploring influencing variables for the acceptance of social robots." *Robotics and Autonomous Systems* 61, no. 12 (2013): 1476-86.

De Melo-Martín, Inmaculada. "Genetically Modified Organisms (GMOs): Human Beings." In *Encyclopedia of Global Bioethics*, edited by Henk ten Have. Springer Science+Business Media Dordrecht. Version of March 13, 2015. doi: 10.1007/978-3-319-05544-2_210-1. Accessed January 21, 2016.

Deep Brain Stimulation for Parkinson's Disease, edited by Gordon H. Baltuch and Matthew B. Stern. Boca Raton: CRC Press, 2007.

Dellon, Brian, and Yoky Matsuoka. "Prosthetics, exoskeletons, and rehabilitation." *IEEE Robotics and Automation magazine* 14, no. 1 (2007): 30.

Denning, Tamara, Alan Borning, Batya Friedman, Brian T. Gill, Tadayoshi Kohno, and William H. Maisel. "Patients, pacemakers, and implantable defibrillators: Human values and security for wireless implantable medical devices." In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 917-26. ACM, 2010.

Denning, Tamara, Yoky Matsuoka, and Tadayoshi Kohno. "Neurosecurity: Security and Privacy for Neural Devices." *Neurosurgical Focus* 27, no. 1 (2009): E7.

Digital Ecosystems: Society in the Digital Age, edited by Łukasz Jonak, Natalia Juchniewicz, and Renata Włoch. Warsaw: Digital Economy Lab, University of Warsaw, 2016.

DoD Architecture Framework Version 2.02. US Department of Defense, August 2010. http://dodcio.defense.gov/Portals/0/Documents/DODAF/DoDAF_v2-02_web.pdf. Accessed December 4, 2016.

Dormer, Kenneth J. "Implantable electronic otologic devices for hearing rehabilitation." In *Handbook of Neuroprosthetic Methods*, edited by Warren E. Finn and Peter G. LoPresti, pp. 237-60. Boca Raton: CRC Press, 2003.

Drummond, Katie. "Pentagon Preps Soldier Telepathy Push." *Wired*, May 14, 2009. https://www.wired.com/2009/05/pentagon-preps-soldier-telepathy-push/. Accessed December 5, 2016.

Dudai, Yadin. "The Neurobiology of Consolidations, Or, How Stable Is the Engram?" *Annual Review of Psychology* 55 (2004): 51-86.

Dumas II, Joseph D. *Computer Architecture: Fundamentals and Principles of Computer Design*. Boca Raton: CRC Press, 2006.

Edlinger, Günter, Cristiano Rizzo, and Christoph Guger. "Brain Computer Interface." In *Springer Handbook of Medical Technology*, edited by Rüdiger Kramme, Klaus-Peter Hoffmann, and Robert S. Pozos, 1003-17. Springer Berlin Heidelberg, 2011.

Electroreception, edited by Theodore H. Bullock, Carl D. Hopkins, Arthur N. Popper, and Richard R. Fay. New York: Springer Science+Business Media, 2005.

"Employee Tenure Summary." Washington, DC: US Department of Labor, Bureau of Labor Statistics, September 22, 2016. http://www.bls.gov/news.release/tenure.nr0.htm. Accessed November 9, 2016.

Epinephrine in the Central Nervous System, edited by Jon M. Stolk, David C. U'Prichard, and Kjell Fuxe. Oxford University Press, 1988.

Ericsson, K. Anders, and Neil Charness. "Expert performance: Its structure and acquisition." *American Psychologist* 49, no. 8 (1994): 725-47.

Erikson, Jane. "Thought-Controlled Robotic Arm 'Makes a Big Negative a Whole Lot Better'." The University of Arizona Health Sciences, July 2013. http://medicine.arizona.edu/alumni/alumni-slide/thought-controlled-robotic-arm-%E2%80%98makes-big-negative-whole-lot-better%E2%80%99 Accessed December 5, 2016.

Evans, Dave. "The Internet of Everything: How More Relevant and Valuable Connections Will Change the World." Cisco Internet Solutions Business Group: Point of View, 2012. https://www.cisco.com/web/about/ac79/docs/innov/IoE.pdf. Accessed December 16, 2015.

Evans-Pughe, Christine. "Smarter Prosthetics: Researchers Are Working to Develop Artificial Limbs with Almost Life-like Levels of Functionality and Control." *Engineering and Technology* (June 2006): 32-36.

Evolutionary Linguistics, edited by April McMahon and Robert McMahon. New York: Cambridge University Press, 2013.

Fabbro, Franco, Salvatore M. Aglioti, Massimo Bergamasco, Andrea Clarici, and Jaak Panksepp. "Evolutionary aspects of self-and world consciousness in vertebrates." *Frontiers in human neuroscience* 9 (2015).

Fairchild, Alea M. *Technological Aspects of Virtual Organizations: Enabling the Intelligent Enterprise*. Springer Science+Business Media Dordrecht, 2004.

Fairclough, S.H. "Physiological Computing: Interfacing with the Human Nervous System." In *Sensing Emotions*, edited by J. Westerink, M. Krans, and M. Ouwerkerk, pp. 1-20. Philips Research Book Series 12. Springer Netherlands, 2010.

Falconer, Bruce. "Defense Research Agency Seeks to Create Supersoldiers." *Government Executive*, November 10, 2003. http://www.govexec.com/defense/2003/11/defense-research-agency-seeks-to-create-supersoldiers/15386/. Accessed May 22, 2016.

Farina, Dario, and Oskar Aszmann. "Bionic limbs: clinical reality and academic promises." *Science Translational Medicine* 6, no. 257 (2014): 257ps12.

Fayerman, Pamela. "Funding, doctors needed if brain stimulation surgery to expand in B.C." *Vancouver Sun*, 03.06.2013. http://www.vancouversun.com/health/Funding+doctors+needed+brain+stimulation+surgery+expand/8054047/story.html. Accessed December 8, 2016.

Federal Enterprise Architecture Framework, version 2. Washington, DC: Office of Management and Budget, January 29, 2013. https://www.whitehouse.gov/sites/default/files/omb/assets/egov_docs/fea_v2.pdf. Accessed November 18, 2016.

Fernandez-Lopez, Helena, José A. Afonso, J. H. Correia, and Ricardo Simoes. "The Need for Standardized Tests to Evaluate the Reliability of Data Transport in Wireless Medical Systems." In *Sensor Systems and Software*, edited by Francisco Martins, Luís Lopes, and Hervé Paulino, pp. 137-45. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering 102. Springer Berlin Heidelberg, 2012.

Ferrando, Francesca. "Posthumanism, Transhumanism, Antihumanism, Metahumanism, and New Materialisms: Differences and Relations." *Existenz: An International Journal in Philosophy, Religion, Politics, and the Arts* 8, no. 2 (Fall 2013): 26-32.

Fiehler, Katja, Immo Schütz, Tina Meller, and Lore Thaler. "Neural correlates of human echolocation of path direction during walking." *Multisensory research* 28, no. 1-2 (2015): 195-226.

"FIPA Device Ontology Specification." Foundation for Intelligent Physical Agents (FIPA), May 10, 2002. http://www.fipa.org/assets/XC00091D.pdf. Accessed February 9, 2015.

Fleischmann, Kenneth R. "Sociotechnical Interaction and Cyborg–Cyborg Interaction: Transforming the Scale and Convergence of HCI." *The Information Society* 25, no. 4 (2009): 227-35.

"An Ontology of Neuroprostheses as Instruments of 'Cyborgization': Portals to the Experience of Posthumanized Digital-Physical Worlds," Chapter Three in Gladden, Matthew E., Neuroprosthetic Supersystems Architecture, pp. 113-45. Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-07-8 (print edition) and 978-1-944373-08-5 (ebook).

Fountas, Kostas N., and J. R. Smith. "A Novel Closed-Loop Stimulation System in the Control of Focal, Medically Refractory Epilepsy." In *Operative Neuromodulation*, edited by Damianos E. Sakas and Brian A. Simpson, 357-62. Acta Neurochirurgica Supplements 97/2. Springer Vienna, 2007.

Frewer, Lynn J., Ivo A. van der Lans, Arnout RH Fischer, Machiel J. Reinders, Davide Menozzi, Xiaoyong Zhang, Isabelle van den Berg, and Karin L. Zimmermann. "Public perceptions of agri-food applications of genetic modification – A systematic review and meta-analysis." *Trends in Food Science & Technology* 30, no. 2 (2013): 142-52.

Frewer Lynn, Jesper Lassen, B. Kettlitz, Joachim Scholderer, Volkert Beekman, and Knut G. Berdal. "Societal aspects of genetically modified foods." *Food and Chemical Toxicology* 42, no. 7 (2004): 1181-93.

Friedenberg, Jay. *Artificial Psychology: The Quest for What It Means to Be Human*. Philadelphia: Psychology Press, 2008.

Friedman, Batya, and Helen Nissenbaum. "Bias in Computer Systems." In *Human Values and the Design of Computer Technology*, edited by Batya Friedman, pp. 21-40. CSL Lecture Notes 72. Cambridge: Cambridge University Press, 1997.

Fritz, Robert. *Corporate Tides: The Inescapable Laws of Organizational Structure*. San Francisco: Berret-Koehler, 1996.

Fukuyama, Francis. *Our Posthuman Future: Consequences of the Biotechnology Revolution*. New York: Farrar, Straus, and Giroux, 2002.

The Future of Bioethics: International Dialogues, edited by Akira Akabayashi, Oxford: Oxford University Press, 2014.

Gallego, Juan Álvaro, Eduardo Rocon, Juan Manuel Belda-Lois, and José Luis Pons. "A neuroprosthesis for tremor management through the control of muscle co-contraction." *Journal of neuroengineering and rehabilitation* 10, no. 1 (2013): 1.

Gammelgård, Magnus, Mårten Simonsson, and Åsa Lindström. "An IT Management Assessment Framework: Evaluating Enterprise Architecture Scenarios." *Information Systems and E-Business Management* 5, no. 4 (2007): 415-35.

Garg, Anant Bhaskar. "Embodied Cognition, Human Computer Interaction, and Application Areas." In *Computer Applications for Web, Human Computer Interaction, Signal and Image Processing, and Pattern Recognition*, pp. 369-74. Springer Berlin Heidelberg, 2012.

Gasson, M.N. "Human ICT Implants: From Restorative Application to Human Enhancement." In *Human ICT Implants: Technical, Legal and Ethical Considerations*, edited by Mark N. Gasson, Eleni Kosta, and Diana M. Bowman, pp. 11-28. Information Technology and Law Series 23. T. M. C. Asser Press, 2012.

Gasson, M.N. "ICT implants." In *The Future of Identity in the Information Society*, edited by S. Fischer-Hübner, P. Duquenoy, A. Zuccato, and L. Martucci, pp. 287-95. Springer US, 2008.

Gasson, M.N., Kosta, E., and Bowman, D.M. "Human ICT Implants: From Invasive to Pervasive." In *Human ICT Implants: Technical, Legal and Ethical Considerations*, edited by Mark N. Gasson, Eleni Kosta, and Diana M. Bowman, pp. 1-8. Information Technology and Law Series 23. T. M. C. Asser Press, 2012.

Gen, Mitsuo, Runwei Cheng, and Lin Lin. *Network Models and Optimization: Multiobjective Genetic Algorithm Approach.* Springer-Verlag London Limited, 2008.

Gene Therapy of the Central Nervous System: From Bench to Bedside, edited by Michael G. Kaplitt and Matthew J. During. Amsterdam: Elsevier, 2006.

Gill, Satinder P. "Socio-Ethics of Interaction with Intelligent Interactive Technologies." *AI & SOCIETY* 22, no. 3 (October 26, 2007): 283-300.

Giustozzi, Emilie Steele, and Betsy Van der Veer Martens. "The new competitive intelligence agents: 'Programming' competitive intelligence ethics into corporate cultures." *Webology* 8, no. 2 (2011): 1.

Gladden, Matthew E. "The Artificial Life-Form as Entrepreneur: Synthetic Organism-Enterprises and the Reconceptualization of Business." In *Proceedings of the Fourteenth International Conference on the Synthesis and Simulation of Living Systems*, edited by Hiroki Sayama, John Rieffel, Sebastian Risi, René Doursat and Hod Lipson, pp. 417-18. The MIT Press, 2014.

Gladden, Matthew E. "Cryptocurrency with a Conscience: Using Artificial Intelligence to Develop Money that Advances Human Ethical Values." *Annales: Ethics in Economic Life* 18, no. 4 (2015): 85-98.

Gladden, Matthew E. "Cybershells, Shapeshifting, and Neuroprosthetics: Video Games as Tools for Posthuman 'Body Schema (Re)Engineering'." Keynote presentation at the Ogólnopolska Konferencja Naukowa Dyskursy Gier Wideo, Facta Ficta / AGH, Kraków, June 6, 2015.

Gladden, Matthew E. "The Diffuse Intelligent Other: An Ontology of Nonlocalizable Robots as Moral and Legal Actors." In *Social Robots: Boundaries, Potential, Challenges*, edited by Marco Nørskov, pp. 177-98. Farnham: Ashgate, 2016.

Gladden, Matthew E. "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems: The Impact of Posthuman Neuroprosthetics on the Creation of Strategic, Structural, Functional, Technological, and Sociocultural Alignment." Thesis project, MBA in Innovation and Data Analysis. Warsaw: Institute of Computer Science, Polish Academy of Sciences, 2016.

Gladden, Matthew E. "From Stand Alone Complexes to Memetic Warfare: Cultural Cybernetics and the Engineering of Posthuman Popular Culture." Presentation at the 50 Shades of Popular Culture International Conference. Facta Ficta / Uniwersytet Jagielloński, Kraków, February 19, 2016.

Gladden, Matthew E. *The Handbook of Information Security for Advanced Neuroprosthetics*. Indianapolis: Synthypnion Academic, 2015.

Gladden, Matthew E. "Implantable Computers and Information Security: A Managerial Perspective." In *Posthuman Management: Creating Effective Organizations in an Age of Social Robotics, Ubiquitous AI, Human Augmentation, and Virtual Worlds*. Second edition, pp. 285-300. Indianapolis: Defragmenter Media, 2016.

Gladden, Matthew E. "Information Security Concerns as a Catalyst for the Development of Implantable Cognitive Neuroprostheses." In *9th Annual EuroMed Academy of Business (EMAB) Conference: Innovation, Entrepreneurship and Digital Ecosystems (EUROMED 2016) Book of Proceedings*, edited by Demetris Vrontis, Yaakov Weber, and Evangelos Tsoukatos, pp. 891-904. Engomi: EuroMed Press, 2016.

Gladden, Matthew E. "Leveraging the Cross-Cultural Capacities of Artificial Agents as Leaders of Human Virtual Teams." *Proceedings of the 10th European Conference on Management Leadership and Governance*, edited by Visnja Grozdanić, pp. 428-35. Reading: Academic Conferences and Publishing International Limited, 2014.

Gladden, Matthew E. "Managerial Robotics: A Model of Sociality and Autonomy for Robots Managing Human Beings and Machines." *International Journal of Contemporary Management* 13, no. 3 (2014): 67-76.

Gladden, Matthew E. "Managing the Ethical Dimensions of Brain-Computer Interfaces in eHealth: An SDLC-based Approach." In 9th *Annual EuroMed Academy of Business (EMAB) Conference: Innovation, Entrepreneurship and Digital Ecosystems (EUROMED 2016) Book of*

Proceedings, edited by Demetris Vrontis, Yaakov Weber, and Evangelos Tsoukatos, pp. 876-90. Engomi: EuroMed Press, 2016.

Gladden, Matthew E. "Neural Implants as Gateways to Digital-Physical Ecosystems and Posthuman Socioeconomic Interaction." In *Digital Ecosystems: Society in the Digital Age*, edited by Łukasz Jonak, Natalia Juchniewicz, and Renata Włoch, pp. 85-98. Warsaw: Digital Economy Lab, University of Warsaw, 2016.

Gladden, Matthew E. "Neuromarketing Applications of Neuroprosthetic Devices: An Assessment of Neural Implants' Capacities for Gathering Data and Influencing Behavior." In *9th Annual EuroMed Academy of Business (EMAB) Conference: Innovation, Entrepreneurship and Digital Ecosystems (EUROMED 2016) Book of Proceedings*, edited by Demetris Vrontis, Yaakov Weber, and Evangelos Tsoukatos, pp. 905-18. Engomi: EuroMed Press, 2016.

Gladden, Matthew E. "Organization Development and the Robotic-Cybernetic-Human Workforce: Humanistic Values for a Posthuman Future?" In *Posthuman Management: Creating Effective Organizations in an Age of Social Robotics, Ubiquitous AI, Human Augmentation, and Virtual Worlds*. Second edition, pp. 239-55. Indianapolis: Defragmenter Media, 2016.

Gladden, Matthew E. *Posthuman Management: Creating Effective Organizations in an Age of Social Robotics, Ubiquitous AI, Human Augmentation, and Virtual Worlds*. Second edition. Indianapolis: Defragmenter Media, 2016.

Gladden, Matthew E. *Sapient Circuits and Digitalized Flesh: The Organization as Locus of Technological Posthumanization*. Indianapolis: Defragmenter Media, 2016.

Gladden, Matthew E. "The Social Robot as 'Charismatic Leader': A Phenomenology of Human Submission to Nonhuman Power." In *Sociable Robots and the Future of Social Relations: Proceedings of Robo-Philosophy 2014*, edited by Johanna Seibt, Raul Hakli, and Marco Nørskov, pp. 329-39. Frontiers in Artificial Intelligence and Applications 273. IOS Press, 2014.

Gladden, Matthew E. "Utopias and Dystopias as Cybernetic Information Systems: Envisioning the Posthuman Neuropolity." *Creatio Fantastica* nr 3 (50) (2015).

Gockley, Rachel, Allison Bruce, Jodi Forlizzi, Marek Michalowski, Anne Mundell, Stephanie Rosenthal, Brennan Sellner, Reid Simmons, Kevin Snipes, Alan C. Schultz, and Jue Wang. "Designing Robots for Long-Term Social Interaction." In *2005 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2005)*, pp. 2199-2204. 2005.

Goldstein, E. Bruce. *Sensation and Perception.* Ninth edition. Belmont, CA: Wadsworth / CENGAGE Learning, 2014.

Goleman, Daniel. "What Makes a Leader?" *Harvard Business Review* 82 (1) (2004): 82-91.

Goodman, H. Maurice. *Basic Medical Endocrinology.* Fourth edition. Burlington, MA: Academic Press, 2009.

Graham, Stephen. "Imagining Urban Warfare: Urbanization and U.S. Military Technoscience." In *War, Citizenship, Territory*, edited by Deborah Cowen and Emily Gilbert. New York: Routledge, 2008.

Greve, Andrea, and Richard Henson. "What We Have Learned about Memory from Neuroimaging." In *The Wiley Handbook on the Cognitive Neuroscience of Memory*, edited by Donna Rose Addis, Morgan Barense, and Audrey Duarte, pp. 1-20. Malden, MA: John Wiley & Sons Ltd., 2015.

Grottke, M., H. Sun, R.M. Fricks, and K.S. Trivedi. "Ten fallacies of availability and reliability analysis." In *Service Availability*, pp. 187-206. Lecture Notes in Computer Science 5017. Springer Berlin Heidelberg, 2008.

Gunkel, David J. *The Machine Question: Critical Perspectives on AI, Robots, and Ethics*. Cambridge, MA: The MIT Press, 2012.

"An Ontology of Neuroprostheses as Instruments of 'Cyborgization': Portals to the Experience of Posthumanized Digital-Physical Worlds," Chapter Three in Gladden, Matthew E., Neuroprosthetic Supersystems Architecture, pp. 113-45. Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-07-8 (print edition) and 978-1-944373-08-5 (ebook).

Gutnick, Tamar, Ruth A. Byrne, Binyamin Hochner, and Michael Kuba. "Octopus vulgaris uses visual information to determine the location of its arm." *Current Biology* 21, no. 6 (2011): 460-62.

Haki, Mohammad Kazem, Christine Legner, and Frederik Ahlemann. "Beyond EA Frameworks: Towards an Understanding of the Adoption of Enterprise Architecture Management." *ECIS 2012 Proceedings*, 2012.

Hameroff, Stuart, and Roger Penrose. "Consciousness in the universe: A review of the 'Orch OR' theory." *Physics of Life Reviews* 11, no. 1 (2014): 39-78.

Han, J.-H., S.A. Kushner, A.P. Yiu, H.-W. Hsiang, T. Buch, A. Waisman, B. Bontempi, R.L. Neve, P.W. Frankland, and S.A. Josselyn. "Selective Erasure of a Fear Memory." *Science* 323, no. 5920 (2009): 1492-96.

Hand, Eric. "Maverick scientist thinks he has discovered magnetic sixth sense in humans." *Science*, June 23, 2016. doi:10.1126/science.aaf5803. Accessed December 8, 2016.

Handbook of Cloud Computing, edited by Borko Furht and Armando Escalante. New York: Springer, 2010.

Handbook of Psychology, Volume 6: Developmental Psychology, edited by Richard M. Lerner, M. Ann Easterbrooks, and Jayanthi Mistry. Hoboken: John Wiley & Sons, Inc., 2003.

Hanson, R. "If uploads come first: The crack of a future dawn." *Extropy* 6, no. 2 (1994): 10-15.

Haraway, Donna. *Simians, Cyborgs, and Women: The Reinvention of Nature*. New York: Routledge, 1991.

Hargrove, Levi J., Ann M. Simon, Aaron J. Young, Robert D. Lipschutz, Suzanne B. Finucane, Douglas G. Smith, and Todd A. Kuiken. "Robotic leg control with EMG decoding in an amputee with nerve transfers." *New England Journal of Medicine* 369, no. 13 (2013): 1237-42.

Harman, Gilbert. *Thought.* Princeton: Princeton University Press, 1973.

Hatfield, B., A. Haufler, and J. Contreras-Vidal. "Brain Processes and Neurofeedback for Performance Enhancement of Precision Motor Behavior." In *Foundations of Augmented Cognition. Neuroergonomics and Operational Neuroscience*, edited by Dylan D. Schmorrow, Ivy V. Estabrooke, and Marc Grootjen, pp. 810-17. Lecture Notes in Computer Science 5638. Springer Berlin Heidelberg, 2009.

Haykin, Simon. *Neural Networks and Learning Machines.* Third edition. New York: Pearson Prentice Hall, 2009.

Hayles, N. Katherine. *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics.* Chicago: University of Chicago Press, 1999.

Heim, Michael. *The Metaphysics of Virtual Reality*. New York: Oxford University Press, 1993.

Henderson, John C., and H. Venkatraman. "Strategic alignment: Leveraging information technology for transforming organizations." *IBM systems journal* 32, no. 1 (1993): 472-84.

Herbrechter, Stefan. *Posthumanism: A Critical Analysis*. London: Bloomsbury, 2013. [Kindle edition.]

Herzberg, Frederick. "One more time: How do you motivate employees." In *The Leader-Manager*, edited by John N. Williamson, pp. 433-48. New York: John Wiley & Sons, Inc., 1986.

Heylighen, Francis. "The Global Brain as a New Utopia." In *Renaissance der Utopie. Zukunftsfiguren des 21. Jahrhunderts*, edited by R. Maresch and F. Rötzer. Frankfurt: Suhrkamp, 2002.

Hochmair, Ingeborg. "Cochlear Implants: Facts." MED-EL, September 2013. http://www.medel.com/cochlear-implants-facts. Accessed December 8, 2016.

Hoffmann, Klaus-Peter, and Silvestro Micera. "Introduction to Neuroprosthetics." In *Springer Handbook of Medical Technology*, edited by Rüdiger Kramme, Klaus-Peter Hoffmann, and Robert S. Pozos, pp. 785-800. Springer Berlin Heidelberg, 2011.

Højsgaard, Hjalte. "Market-Driven Enterprise Architecture." *Journal of Enterprise Architecture* 7, no. 1 (2011), 28.

Hoogervorst, Jan. "Enterprise Architecture: Enabling Integration, Agility and Change." *International Journal of Cooperative Information Systems* 13, no. 03 (2004): 213-33.

Horling, Bryan, and Victor Lesser. "A Survey of Multi-Agent Organizational Paradigms." *The Knowledge Engineering Review* 19, no. 04 (2004): 281-316.

Howard, Robert. "The CEO as Organizational Architect: An Interview with Xerox's Paul Allaire." *Harvard Business Review* 70 (5) (1992): 106-21.

Hutchinson, Douglas T. "The quest for the bionic arm." *Journal of the American Academy of Orthopaedic Surgeons* 22, no. 6 (2014): 346-51.

Iacob, Maria-Eugenia, Lucas O. Meertens, Henk Jonkers, Dick A.C. Quartel, Lambert J.M. Nieuwenhuis, and M.J. Van Sinderen. "From Enterprise Architecture to Business Models and Back." *Software & Systems Modeling* 13, no. 3 (2012): 1059-83.

Implantable Biomedical Microsystems: Design Principles and Applications, edited by Swarup Bhunia, Steve Majerus, and Mohamad Sawan. Oxford: William Andrew, 2015.

Implantable Neuroprostheses for Restoring Function, edited by Kevin Kilgore. Cambridge: Woodhead Publishing, 2015.

Implantable Sensor Systems for Medical Applications, edited by Andreas Inmann and Diana Hodgins. Woodhead Publishing, 2013.

Information Storage and Management: Storing, Managing, and Protecting Digital Information in Classic, Virtualized, and Cloud Environments. Second edition. Edited by Somasundaram Gnanasundaram and Alok Shrivastava. Indianapolis: John Wiley & Sons, Inc., 2012.

ISO 15704:2000, Industrial automation systems – Requirements for enterprise-reference architectures and methodologies. ISO/TC 184/SC5. Geneva: ISO, 2000.

ISO 19439:2006, Enterprise integration – Framework for enterprise modelling. ISO/TC 184/SC5. Geneva: ISO, 2006.

ISO 27799:2016, Health informatics – Information security management in health using ISO/IEC 27002. ISO/TC 215. Geneva: ISO, 2016.

ISO/IEC 15288:2002, Systems engineering – System life cycle processes. ISO/IEC JTC 1/SC 7. Geneva: ISO, 2002.

ISO/IEC 7498-1:1994, Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model. ISO/IEC JTC 1. Geneva: ISO, 1994.

ISO/IEC/IEEE 42010:2010, Systems and software engineering – Architecture description. ISO/IEC JTC 1/SC 7. Geneva: ISO, 2011.

Johar, Swati. *Emotion, Affect and Personality in Speech: The Bias of Language and Paralanguage*. SpringerNature, 2016.

Josselyn, Sheena A. "Continuing the Search for the Engram: Examining the Mechanism of Fear Memories." *Journal of Psychiatry & Neuroscience : JPN* 35, no. 4 (2010): 221-28.

Jürgens, Uta, and Danko Nikolić. "Ideaesthesia: conceptual processes assign similar colours to similar shapes." *Translational Neuroscience* 3, no. 1 (2012): 22-27.

Kalat, James W. *Biological Psychology.* Ninth edition. Belmont, CA: Thomson Wadsworth, 2007.

Kanda, Takayuki, and Hiroshi Ishiguro. *Human-Robot Interaction in Social Robotics*. Boca Raton: CRC Press, 2013.

Kandjani, Hadi, Peter Bernus, and Lian Wen. "Enterprise Architecture Cybernetics for Complex Global Software Development: Reducing the Complexity of Global Software Development Using Extended Axiomatic Design Theory." In *2012 IEEE Seventh International Conference on Global Software Engineering*, pp. 169-73. IEEE, 2012.

Kaplan, Robert S., and David P. Norton. *The Strategy-Focused Organization: How Balanced Scorecard Companies Thrive in the New Business Environment*. Boston: Harvard Business School Press, 2001.

Katz, Gregory. "The hypothesis of a genetic protolanguage: An epistemological investigation." *Biosemiotics* 1, no. 1 (2008): 57-73.

Kazienko, Przemysław, Radosław Michalski, and Sebastian Palus. "Social Network Analysis as a Tool for Improving Enterprise Architecture." In *Agent and Multi-Agent Systems: Technologies and Applications*, edited by James O'Shea, Ngoc Thanh Nguyen, Keeley Crockett, Robert J. Howlett, and Lakhmi C. Jain, pp. 651-60. Lecture Notes in Computer Science 6682. Springer Berlin Heidelberg, 2011.

Keenan, James F. "Enhancing Prosthetics for Soldiers Returning from Combat with Disabilities." *ET Studies* 4, no. 1 (2013): 69-88.

Kelly, Kevin. "A Taxonomy of Minds." *The Technium*, February 15, 2007. http://kk.org/thetechnium/a-taxonomy-of-m/. Accessed January 25, 2016.

Kelly, Kevin. "The Landscape of Possible Intelligences." *The Technium*, September 10, 2008. http://kk.org/thetechnium/the-landscape-o/. Accessed January 25, 2016.

Kelly, Kevin. *Out of Control: The New Biology of Machines, Social Systems and the Economic World*. Basic Books, 1994.

Kerr, Paul K., John Rollins, and Catherine A. Theohary. "The Stuxnet Computer Worm: Harbinger of an Emerging Warfare Capability." Congressional Research Service, 2010.

Kim, Kwang Jin, Xiaobo Tan, Hyouk Ryeol Choi, and David Pugal. *Biomimetic Robotic Artificial Muscles.* Singapore: World Scientific Publishing Co. Pte. Ltd., 2013.

Kinicki, Angelo, and Brian Williams. *Management: A Practical Introduction*. Fifth edition. New York: McGraw Hill, 2010.

KleinOsowski, A., Ethan H. Cannon, Phil Oldiges, and Larry Wissel. "Circuit design and modeling for soft errors." *IBM Journal of Research and Development* 52, no. 3 (2008): 255-63.

Koene, Randal A. "Embracing Competitive Balance: The Case for Substrate-Independent Minds and Whole Brain Emulation." In *Singularity Hypotheses*, edited by Amnon H. Eden, James H. Moor, Johnny H. Søraker, and Eric Steinhart, pp. 241-67. The Frontiers Collection. Springer Berlin Heidelberg, 2012.

Kohno, T., T. Denning, and Y. Matsuoka. "Security and Privacy for Neural Devices." *Neurosurgical Focus* 27 (2009): 1-4.

Koltko-Rivera, Mark E. "The potential societal impact of virtual reality." *Advances in virtual environments technology: Musings on design, evaluation, and applications* 9 (2005).

Koops, B.-J., and R. Leenes. "Cheating with Implants: Implications of the Hidden Information Advantage of Bionic Ears and Eyes." In *Human ICT Implants: Technical, Legal and Ethical Considerations*, edited by Mark N. Gasson, Eleni Kosta, and Diana M. Bowman, pp. 113-34. Information Technology and Law Series 23. T. M. C. Asser Press, 2012.

Kosta, E., and D.M. Bowman, "Implanting Implications: Data Protection Challenges Arising from the Use of Human ICT Implants." In *Human ICT Implants: Technical, Legal and Ethical Considerations*, edited by Mark N. Gasson, Eleni Kosta, and Diana M. Bowman, pp. 97-112. Information Technology and Law Series 23. T. M. C. Asser Press, 2012.

Kostov, Aleksander, and Mark Polak. "Parallel man-machine training in development of EEG-based cursor control." *IEEE Transactions on Rehabilitation Engineering* 8, no. 2 (2000): 203-05.

Kourany, J.A. "Human Enhancement: Making the Debate More Productive." *Erkenntnis* 79, no. 5 (2013): 981-98.

Kowalewska, Agata. "Symbionts and Parasites – Digital Ecosystems." In *Digital Ecosystems: Society in the Digital Age*, edited by Łukasz Jonak, Natalia Juchniewicz, and Renata Włoch, pp. 73-84. Warsaw: Digital Economy Lab, University of Warsaw, 2016.

Kraemer, Felicitas. "Me, Myself and My Brain Implant: Deep Brain Stimulation Raises Questions of Personal Authenticity and Alienation." *Neuroethics* 6, no. 3 (May 12, 2011): 483-97. doi:10.1007/s12152-011-9115-7.

Krishnan, Armin. "Enhanced Warfighters as Private Military Contractors." In *Super Soldiers: The Ethical, Legal and Social Implications*, edited by Jai Galliott and Mianna Lotz. London: Routledge, 2015.

Krishnan, Armin. "From Psyops to Neurowar: What Are the Dangers?" ISAC-ISSS 2014 Annual Conference on Security Studies. University of Texas, Austin, Texas, November 16, 2014. http://web.isanet.org/Web/Conferences/ISSS%20Austin%202014/Archive/b137347c-6281-466d-b9e7-ef7e0e5d363c.pdf. Accessed May 8, 2016.

Kruchten, Philippe B. "The 4+1 view model of architecture." *IEEE software* 12, no. 6 (1995): 42-50.

Kshirsagar, Sumedha, Chris Joslin, Won-Sook Lee, and Nadia Magnenat-Thalmann. "Personalized Face and Speech Communication over the Internet." In *Proceedings of IEEE Virtual Reality 2001*, edited by Haruo Takemura and Kiyoshi Kiyokawa, pp. 37-44. Los Alamitos, CA: IEEE, 2001.

Kusek, Kristen. "The $3 Million Suit: Wyss Institute Wins DARPA Grant to Further Develop its Soft Exosuit." *Harvard Gazette*, September 11, 2014. http://news.harvard.edu/gazette/story/2014/09/the-3-million-suit/. Accessed December 5, 2016.

Kyllonen, Patrick C., and Raymond E. Christal. "Reasoning ability is (little more than) working-memory capacity?!" *Intelligence* 14, no. 4 (1990): 389-433.

LaFleur, Karl, Kaitlin Cassady, Alexander Doud, Kaleb Shades, Eitan Rogin, and Bin He. "Quadcopter control in three-dimensional space using a noninvasive motor imagery-based brain-computer interface." *Journal of neural engineering* 10, no. 4 (2013): 046003.

Lamm, Ehud, and Ron Unger. *Biological Computation.* Boca Raton: CRC Press, 2011.

Land, Martin Op 't, Erik Proper, Maarten Waage, Jeroen Cloo, and Claudia Steghuis. "Positioning Enterprise Architecture." In *Enterprise Architecture*, pp. 25-47. The Enterprise Engineering Series. Springer Berlin Heidelberg, 2009.

Lebedev, M. "Brain-Machine Interfaces: An Overview." *Translational Neuroscience* 5, no. 1 (March 28, 2014): 99-110.

Leder, Felix, Tillmann Werner, and Peter Martini. "Proactive Botnet Countermeasures: An Offensive Approach." In *The Virtual Battlefield: Perspectives on Cyber Warfare,* volume 3, edited by Christian Czosseck and Kenneth Geers, pp. 211-25. IOS Press, 2009.

Leed, Maren. *Offensive Cyber Capabilities at the Operational Level: The Way Ahead*. Washington, DC: Center for Strategic and International Studies, 2013.

"An Ontology of Neuroprostheses as Instruments of 'Cyborgization': Portals to the Experience of Posthumanized Digital-Physical Worlds,"
Chapter Three in Gladden, Matthew E., Neuroprosthetic Supersystems Architecture, pp. 113-45. Indianapolis: Synthypnion Academic, 2017.
ISBN 978-1-944373-07-8 (print edition) and 978-1-944373-08-5 (ebook).

Li, S., F. Hu, and G. Li, "Advances and Challenges in Body Area Network." In *Applied Informatics and Communication*, edited by J. Zhan, pp. 58-65. Communications in Computer and Information Science 22. Springer Berlin Heidelberg, 2011.

Lilley, Stephen. *Transhumanism and Society: The Social Debate over Human Enhancement*. Springer Science & Business Media, 2013.

Lin, James C. "Hearing microwaves: The microwave auditory phenomenon." *IEEE Antennas and Propagation Magazine* 43, no. 6 (2001): 166-68.

Lind, Jürgen. "Issues in agent-oriented software engineering." In *Agent-Oriented Software Engineering*, pp. 45-58. Springer Berlin Heidelberg, 2001.

Lindström, Åsa, Pontus Johnson, Erik Johansson, Mathias Ekstedt, and Mårten Simonsson. "A Survey on CIO Concerns – Do Enterprise Architecture Frameworks Support Them?" *Information Systems Frontiers* 8, no. 2 (2006).

Ling, Geoffrey SF, Peter Rhee, and James M. Ecklund. "Surgical innovations arising from the Iraq and Afghanistan wars." *Annual review of medicine* 61 (2010): 457-68.

Linsenmeier, Robert A. "Retinal Bioengineering." In *Neural Engineering*, edited by Bin He, pp. 421-84. Bioelectric Engineering. Springer US, 2005.

Liu, Hanjun, and Manwa L. Ng. "Electrolarynx in voice rehabilitation," *Auris Nasus Larynx* 34, no. 3 (2007): 327-32.

Liu, Kecheng, Lily Sun, Dian Jambari, Vaughan Michell, and Sam Chong. "A Design of Business-Technology Alignment Consulting Framework." In *Advanced Information Systems Engineering*, edited by Haralambos Mouratidis and Colette Rolland, pp. 422-35. Lecture Notes in Computer Science 6741. Springer Berlin Heidelberg, 2011.

Lloyd, David. "Biological Time Is Fractal: Early Events Reverberate over a Life Time." *Journal of Biosciences* 33, no. 1 (March 1, 2008): 9-19.

LoBello, Lucia, and Emanuele Toscano. "An adaptive approach to topology management in large and dense real-time wireless sensor networks." *IEEE Transactions on Industrial Informatics* 5, no. 3 (2009): 314-24.

Logan, Lynne Romeiser. "Rehabilitation techniques to maximize spasticity management." *Topics in stroke rehabilitation* 18, no. 3 (2011): 203-11.

Lohn, Andrew J., Patrick R. Mickel, James B. Aimone, Erik P. Debenedictis, and Matthew J. Marinella. "Memristors as Synapses in Artificial Neural Networks: Biomimicry Beyond Weight Change." In *Cybersecurity Systems for Human Cognition Augmentation*, edited by Robinson E. Pino, Alexander Kott, and Michael Shevenell, pp. 135-50. Springer International Publishing, 2014.

Longuet-Higgins, H.C. "Holographic Model of Temporal Recall." *Nature* 217, no. 5123 (1968): 104.

Lorence, Daniel, Anusha Sivaramakrishnan, and Michael Richards. "Transaction-Neutral Implanted Data Collection Interface as EMR Driver: A Model for Emerging Distributed Medical Technologies." *Journal of Medical Systems* 34, no. 4 (March 20, 2009): 609-17.

Luber, B., C. Fisher, P.S. Appelbaum, M. Ploesser, and S.H. Lisanby. "Non-invasive brain stimulation in the detection of deception: Scientific challenges and ethical consequences." *Behavioral Sciences and the Law* 27, no. 2 (2009): 191-208.

Lune, Howard. *Understanding Organizations*, Cambridge: Polity Press, 2010.

Lyon, David. "Beyond Cyberspace: Digital Dreams and Social Bodies." In *Education and Society*, third edition, edited by Joseph Zajda, pp. 221-38. Albert Park: James Nicholas Publishers, 2001.

Ma, Jianhua, Kim-Kwang Raymond Choo, Hui-huang Hsu, Qun Jin, William Liu, Kevin Wang, Yufeng Wang, and Xiaokang Zhou. "Perspectives on Cyber Science and Technology for Cyberization and Cyber-Enabled Worlds." In *2016 IEEE 14th International Conference on Dependable, Autonomic and Secure Computing, 14th International Conference on Pervasive Intelligence and Computing, 2nd International Conference on Big Data Intelligence and Computing and Cyber Science and Technology Congress (DASC/PiCom/DataCom/CyberSciTech)*, pp. 1-9. IEEE, 2016.

Ma, Wei Ji, Masud Husain, and Paul M. Bays. "Changing concepts of working memory." *Nature neuroscience* 17, no. 3 (2014): 347-56.

MacLennan, Elzavita, and Jean-Paul Van Belle. "Factors Affecting the Organizational Adoption of Service-Oriented Architecture (SOA)." *Information Systems and E-Business Management* 12, no. 1 (January 5, 2013): 71-100.

MacVittie, Kevin, Jan Halámek, Lenka Halámková, Mark Southcott, William D. Jemison, Robert Lobel, and Evgeny Katz. "From 'cyborg' lobsters to a pacemaker powered by implantable biofuel cells." *Energy & Environmental Science* 6, no. 1 (2013): 81-86.

Magnetic Stimulation in Clinical Neurophysiology. Second edition. Edited by Mark Hallett and Sudhansu Chokroverty. Philadelphia: Elsevier Butterworth Heinemann, 2005.

Magoulas, Thanos, Aida Hadzic, Ted Saarikko, and Kalevi Pessi. "Alignment in Enterprise Architecture: A Comparative Analysis of Four Architectural Approaches." *Electronic Journal Information Systems Evaluation* 15, no. 1 (2012).

Maguire, Gerald Q., and Ellen M. McGee. "Implantable brain chips? Time for debate." *Hastings Center Report* 29, no. 1 (1999): 7-13.

Maitra, Amit K. "Offensive cyber-weapons: technical, legal, and strategic aspects." *Environment Systems and Decisions* 35, no. 1 (2015): 169-82.

Mak, Stephen. "Ethical Values for E-Society: Information, Security and Privacy." In *Ethics and Policy of Biometrics*, edited by Ajay Kumar and David Zhang, 96-101. Lecture Notes in Computer Science 6005. Springer Berlin Heidelberg, 2010.

Mangun, George R. *The Neuroscience of Attention: Attentional Control and Selection*. Oxford University Press, 2012.

Martin, Richard, and Edward Robertson. "A Comparison of Frameworks for Enterprise Architecture Modeling." In *Conceptual Modeling - ER 2003*, edited by Il-Yeol Song, Stephen W. Liddle, Tok-Wang Ling, and Peter Scheuermann. Lecture Notes in Computer Science 2813. Springer Berlin Heidelberg, 2003.

Mascarenhas, S., R. Prada, A. Paiva, and G.J. Hofstede. "Social Importance Dynamics: A Model for Culturally-Adaptive Agents." In *Intelligent Virtual Agents*, pp. 325-38. Lecture Notes in Computer Science no. 8108. Springer Berlin Heidelberg, 2013.

McCullagh, P., G. Lightbody, J. Zygierewicz, and W.G. Kernohan, "Ethical Challenges Associated with the Development and Deployment of Brain Computer Interface Technology." *Neuroethics* 7, no. 2 (July 28, 2013): 109-22.

McCulloh, Ian A., Helen L. Armstrong, and Anthony N. Johnson. *Social Network Analysis with Applications.* Hoboken, NJ: John Wiley & Sons, Inc., 2013.

McGaugh, James L., and Benno Roozendaal. "Role of adrenal stress hormones in forming lasting memories in the brain." *Current opinion in neurobiology* 12, no. 2 (2002): 205-10.

McGee, E.M. "Bioelectronics and Implanted Devices." In *Medical Enhancement and Posthumanity*, edited by Bert Gordijn and Ruth Chadwick, pp. 207-24. The International Library of Ethics, Law and Technology 2. Springer Netherlands, 2008.

"An Ontology of Neuroprostheses as Instruments of 'Cyborgization': Portals to the Experience of Posthumanized Digital-Physical Worlds," Chapter Three in Gladden, Matthew E., Neuroprosthetic Supersystems Architecture, pp. 113-45. Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-07-8 (print edition) and 978-1-944373-08-5 (ebook).

McGrath, Michael J., and Cliodhna Ní Scanaill. "Regulations and Standards: Considerations for Sensor Technologies." In *Sensor Technologies*, pp. 115-35. Apress, 2013.

McIntosh, Daniel. "The Transhuman Security Dilemma." *Journal of Evolution and Technology* 21, no. 2 (2010): 32-48.

Mehlman, Maxwell J. *Transhumanist Dreams and Dystopian Nightmares: The Promise and Peril of Genetic Engineering*. Baltimore: The Johns Hopkins University Press, 2012.

Mercanzini, André, and Philippe Renaud. *Microfabricated Cortical Neuroprostheses*. Boca Raton: CRC Press, 2010.

Merkel, R., G. Boer, J. Fegert, T. Galert, D. Hartmann, B. Nuttin, and S. Rosahl. "Central Neural Prostheses." In *Intervening in the Brain: Changing Psyche and Society*, pp. 117-60. Ethics of Science and Technology Assessment 29. Springer Berlin Heidelberg, 2007.

Mezzanotte, Sr., Dominic M., and Josh Dehlinger. "Enterprise Architecture: A Framework Based on Human Behavior Using the Theory of Structuration." In *Software Engineering Research, Management and Applications 2012*, edited by Roger Lee, pp. 65-79. Studies in Computational Intelligence 430. Springer Berlin Heidelberg, 2012.

Miah, Andy. "A Critical History of Posthumanism." In *Medical Enhancement and Posthumanity*, edited by Bert Gordijn and Ruth Chadwick, pp. 71-94. The International Library of Ethics, Law and Technology 2. Springer Netherlands, 2008.

Miller, Kai J., and Jeffrey G. Ojemann. "A Simple, Spectral-Change Based, Electrocorticographic Brain–Computer Interface." In *Brain-Computer Interfaces*, edited by Bernhard Graimann, Gert Pfurtscheller, and Brendan Allison, pp. 241-58. The Frontiers Collection. Springer Berlin Heidelberg, 2009.

Miller, Jr., Gerald Alva. "Conclusion: Beyond the Human: Ontogenesis, Technology, and the Posthuman in Kubrick and Clarke's 2001." In *Exploring the Limits of the Human through Science Fiction*, pp. 163-90. American Literature Readings in the 21st Century. Palgrave Macmillan US, 2012.

Min Neo, Hui, and Romain Fonsegrives. "For these 'cyborgs,' keys are so yesterday." AFP / Yahoo! Tech, September 4, 2015. https://www.yahoo.com/tech/cyborgs-keys-yesterday-114442441.html. Accessed December 8, 2016.

"Mind over Mouth? Study Could Lead to Communicating via Thoughts." UCI News, August 13, 2008. https://news.uci.edu/briefs/mind-over-mouth-study-could-lead-to-communicating-via-thoughts/. Accessed December 5, 2016.

Mitcheson, Paul D. "Energy harvesting for human wearable and implantable bio-sensors." In *Engineering in Medicine and Biology Society (EMBC), 2010 Annual International Conference of the IEEE,* pp. 3432-36. IEEE, 2010.

Mizraji, Eduardo, Andrés Pomi, and Juan C. Valle-Lisboa. "Dynamic Searching in the Brain." *Cognitive Neurodynamics* 3, no. 4 (June 3, 2009): 401-14.

Møller, Aage R. *Sensory Systems: Anatomy and Physiology*. Third edition. Aage R Møller, 2014.

Moravec, Hans. *Mind Children: The Future of Robot and Human Intelligence*. Cambridge: Harvard University Press, 1990.

Moreno, Jonathan. "DARPA On Your Mind." *Cerebrum* vol. 6 issue 4 (2004): 92-100.

Moxon, David. *Memory.* Oxford: Heinemann Educational Publishers, 2000.

Mubin, Omar, Christoph Bartneck, Loe Feijs, Hanneke Hooft van Huysduynen, Jun Hu, and Jerry Muelver. "Improving speech recognition with the robot interaction language." *Disruptive Science and Technology* 1, no. 2 (2012): 79-88.

Mubin, Omar, Joshua Henderson, and Christoph Bartneck. "Talk ROILA to your Robot." In *Proceedings of the 15th Conference on International conference on multimodal interaction*, pp. 317-18. ACM, 2013.

Mueller, Scott. *Upgrading and Repairing PCs, 20th Edition*. Indianapolis: Que, 2012.

Mulhauser, Gregory R. "On the end of a quantum mechanical romance." *Psyche* 2, no. 5 (1995).

Murphy, Robin. *Introduction to AI Robotics*. Cambridge, MA: The MIT Press, 2000.

Muscolino, Joseph E. *Kinesiology: The Skeletal System and Muscle Function.* Third edition. St. Louis: Elsevier, 2017.

Nadler, David, and Michael Tushman. *Competing by Design: The Power of Organizational Architecture*. Oxford University Press, 1997. [Kindle edition.]

Nakakawa, Agnes, Patrick van Bommel, and H. A. Erik Proper. "Quality Enhancement in Creating Enterprise Architecture: Relevance of Academic Models in Practice." In *Advances in Enterprise Engineering II*, edited by Erik Proper, Frank Harmsen, and Jan L. G. Dietz, pp. 109-33. Lecture Notes in Business Information Processing 28. Springer Berlin Heidelberg, 2009.

The Nature of Time: Geometry, Physics and Perception, edited by Rosolino Buccheri, Metod Saniga, and William Mark Stuckey. Springer Science+Business Media Dordrecht, 2003.

Nayar, Pramod K. *An Introduction to New Media and Cybercultures.* Chichester: John Wiley & Sons Ltd., 2010.

Negoescu, R. "Conscience and Consciousness in Biomedical Engineering Science and Practice." In *International Conference on Advancements of Medicine and Health Care through Technology*, edited by Simona Vlad, Radu V. Ciupa, and Anca I. Nicu, pp. 209-14. IFMBE Proceedings 26. Springer Berlin Heidelberg, 2009.

Neubauer, André, Jürgen Freudenberger, and Volker Kühn. *Coding Theory: Algorithms, Architectures and Applications*. Chichester: John Wiley & Sons Ltd., 2007.

Neuper, Christa, and Gert Pfurtscheller. "Neurofeedback Training for BCI Control." In *Brain-Computer Interfaces*, edited by Bernhard Graimann, Gert Pfurtscheller, and Brendan Allison, pp. 65-78. The Frontiers Collection. Springer Berlin Heidelberg, 2009.

Neuroimaging and Memory, edited by Jonathan K. Foster. Hove, East Sussex: Psychology Press Ltd., 1999.

The Neuroscience of Sleep, edited by Robert Stickgold and Matthew P. Walker. London: Elsevier, 2009.

Neuweiler, Gerhard. "Evolutionary aspects of bat echolocation." *Journal of Comparative Physiology A* 189, no. 4 (2003): 245-256.

Niku, Saeed B. *Introduction to Robotics: Analysis, Control, Applications.* Second edition. Hoboken: John Wiley & Sons, Inc., 2011.

NIST Special Publication 1800-1b: Securing Electronic Health Records on Mobile Devices: Approach, Architecture, and Security Characteristics. Leah Kauffman, editor-in-chief. Gaithersburg, MD: National Institute of Standards & Technology, 2015.

NIST Special Publication 800-100: Information Security Handbook: A Guide for Managers. Edited by P. Bowen, J. Hash, and M. Wilson. Gaithersburg, MD: National Institute of Standards & Technology, 2006.

NIST Special Publication 800-53, Revision 4: Security and Privacy Controls for Federal Information Systems and Organizations. Joint Task Force Transformation Initiative. Gaithersburg, MD: National Institute of Standards & Technology, 2013.

Niven, Jeremy E. "Invertebrate neurobiology: Visual direction of arm movements in an octopus." *Current Biology* 21, no. 6 (2011): R217-R218.

"An Ontology of Neuroprostheses as Instruments of 'Cyborgization': Portals to the Experience of Posthumanized Digital-Physical Worlds," Chapter Three in Gladden, Matthew E., Neuroprosthetic Supersystems Architecture, pp. 113-45. Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-07-8 (print edition) and 978-1-944373-08-5 (ebook).

Noran, Ovidiu. "A Mapping of Individual Architecture Frameworks (GRAI, PERA, C4ISR, CIMOSA, ZACHMAN, ARIS) onto GERAM." In *Handbook on Enterprise Architecture*, edited by Peter Bernus, Laszlo Nemes, and Günter Schmidt, pp. 65-210. International Handbooks on Information Systems. Springer Berlin Heidelberg, 2003.

Nouvel, Pascal. "A Scale and a Paradigmatic Framework for Human Enhancement." In *Inquiring into Human Enhancement*, edited by Simone Bateman, Jean Gayon, Sylvie Allouche, Jérôme Goffette, and Michela Marzano, pp. 103-18. Palgrave Macmillan UK, 2015.

Novaković, Branko, Dubravko Majetić, Josip Kasać, and Danko Brezak. "Artificial Intelligence and Biorobotics: Is an Artificial Human Being our Destiny?" In *Annals of DAAAM for 2009 & Proceedings of the 20th International DAAAM Symposium "Intelligent Manufacturing & Automation: Focus on Theory, Practice and Education,"* edited by Branko Katalinic, pp. 121-22. Vienna: DAAAM International, 2009.

Null, Linda, and Julia Lobur. *The Essentials of Computer Organization and Architecture*. Second edition. Sudbury, MA: Jones and Bartlett Publishers, 2006.

Obaid, M., I. Damian, F. Kistler, B. Endrass, J. Wagner, and E. André. "Cultural Behaviors of Virtual Agents in an Augmented Reality Environment." In *Intelligent Virtual Agents*, pp. 412-18. Lecture Notes in Computer Science no. 7502. Springer Berlin Heidelberg, 2012.

Ochsner, Beate, Markus Spöhrer, and Robert Stock. "Human, non-human, and beyond: cochlear implants in socio-technological environments." *NanoEthics* 9, no. 3 (2015): 237-50.

Okun, Michael S. "Parkinson's Disease: Guide to Deep Brain Stimulation Therapy." Second edition. National Parkinson Foundation, 2014. http://www.parkinson.org/sites/default/files/Guide_to_DBS_Stimulation_Therapy.pdf. Accessed December 8, 2016.

Olson, Eric T. "Personal Identity." *The Stanford Encyclopedia of Philosophy* (Fall 2015 Edition), edited by Edward N. Zalta. http://plato.stanford.edu/archives/fall2015/entries/identity-personal/. Accessed January 17, 2016.

Osterwalder, Alexander, and Yves Pigneur. *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*. John Wiley & Sons, 2010.

The Oxford Handbook of Philosophy of Perception, edited by Mohan Matthen. Oxford: Oxford University Press, 2015.

Panno, Joseph. *Gene Therapy: Treating Disease by Repairing Genes*. New York: Facts on File, 2005.

Panoulas, Konstantinos J., Leontios J. Hadjileontiadis, and Stavros M. Panas. "Brain-Computer Interface (BCI): Types, Processing Perspectives and Applications." In *Multimedia Services in Intelligent Environments*, edited by George A. Tsihrintzis and Lakhmi C. Jain, pp. 299-321. Smart Innovation, Systems and Technologies 3. Springer Berlin Heidelberg, 2010.

Park, M.C., M.A. Goldman, T.W. Belknap, and G.M. Friehs. "The Future of Neural Interface Technology." In *Textbook of Stereotactic and Functional Neurosurgery*, edited by A.M. Lozano, P.L. Gildenberg, and R.R. Tasker, pp. 3185-3200. Heidelberg/Berlin: Springer, 2009.

Parker, Donn B. "Toward a New Framework for Information Security." In *The Computer Security Handbook*, fourth edition, edited by Seymour Bosworth and M. E. Kabay. John Wiley & Sons, 2002.

Patel, Rajeev, Robert J. Torres, and Peter Rosset. "Genetic engineering in agriculture and corporate engineering in public debate: risk, public relations, and public debate over genetically modified crops." *International journal of occupational and environmental health* 11, no. 4 (2005).

Patil, P.G., and D.A. Turner. "The Development of Brain-Machine Interface Neuroprosthetic Devices." In *Neurotherapeutics* 5, no. 1 (January 1, 2008): 137-46.

Patoine, Brenda. "Progress Report 2010: Deep Brain Stimulation – The 2010 Progress Report on Brain Research." The Dana Foundation, January 2010. http://www.dana.org/Publications/ReportDetails.aspx?id=44348. Accessed December 8, 2016.

Payr, S., and Trappl, R. "Agents across Cultures." In *Intelligent Virtual Agents*, pp. 320-24. Lecture Notes in Computer Science 2792. Springer Berlin Heidelberg, 2003.

Pazzaglia, Mariella, and Marco Molinari. "The embodiment of assistive devices – from wheelchair to exoskeleton." *Physics of Life Reviews* 16 (2016): 163-75.

Pearce, David. "The Biointelligence Explosion." In *Singularity Hypotheses*, edited by A.H. Eden, J.H. Moor, J.H. Søraker, and E. Steinhart, pp. 199-238. The Frontiers Collection. Berlin/Heidelberg: Springer, 2012.

Peigneux, Philippe. "Neuroimaging Studies of Sleep and Memory in Humans." In *Sleep, Neuronal Plasticity and Brain Function*, edited by Peter Meerlo, Ruth M. Benca, and Ted Abel, pp. 239-68. Springer Berlin Heidelberg, 2015.

Pérez Ríos, José. "Systems Thinking, Organisational Cybernetics and the Viable System Model." In *Design and Diagnosis for Sustainable Organizations*, pp. 1-64. Springer Berlin Heidelberg, 2012.

Peterson, David J. *The Art of Language Invention: From Horse-Lords to Dark Elves, The Words Behind World-Building*. New York: Penguin Books, 2015.

Pino, Robinson E., and Alexander Kott. "Neuromorphic Computing for Cognitive Augmentation in Cyber Defense." In *Cybersecurity Systems for Human Cognition Augmentation,* edited by Robinson E. Pino, Alexander Kott, and Michael Shevenell, pp. 19-46. Springer International Publishing, 2014.

Polcar, Jiri, and Petr Horejsi. "Knowledge Acquisition and Cyber Sickness: A Comparison of VR Devices in Virtual Tours." *MM Science Journal* (June 2015): 613-16.

Pollatsek, Alexander. "The Role of Sound in Silent Reading." In *The Oxford Handbook of Reading*, edited by Alexander Pollatsek and Rebecca Treiman, pp. 185-201. New York: Oxford University Press, 2015.

Postmarket Management of Cybersecurity in Medical Devices: Draft Guidance for Industry and Food and Drug Administration Staff. Silver Spring, MD: US Food and Drug Administration, 2016.

Prestes, E., J.L. Carbonera, S. Rama Fiorini, V.A.M. Jorge, M. Abel, R. Madhavan, A. Locoro, et al. "Towards a Core Ontology for Robotics and Automation." *Robotics and Autonomous Systems* 61, no. 11 (November 2013): 1193-1204.

Pribram, K.H. "Prolegomenon for a Holonomic Brain Theory." In *Synergetics of Cognition*, edited by Hermann Haken and Michael Stadler, pp. 150-84. Springer Series in Synergetics 45. Springer Berlin Heidelberg, 1990.

Pribram, K.H., and S.D. Meade. "Conscious Awareness: Processing in the Synaptodendritic Web – The Correlation of Neuron Density with Brain Size." *New Ideas in Psychology* 17, no. 3 (December 1, 1999): 205-14.

Primer on the Autonomic Nervous System. Third edition. Edited by David Robertson, Italo Biaggioni, Geoffrey Burnstock, Phillip A. Low, and Julian F.R. Paton. London: Academic Press, 2012.

Principe, José C., and Dennis J. McFarland. "BMI/BCI Modeling and Signal Processing." In *Brain-Computer Interfaces*, pp. 47-64. Springer Netherlands, 2008.

"Products and Procedures." Medtronic, 2016. http://professional.medtronic.com/pt/neuro/dbs-md/prod/index.htm. Accessed December 8, 2016.

"An Ontology of Neuroprostheses as Instruments of 'Cyborgization': Portals to the Experience of Posthumanized Digital-Physical Worlds," Chapter Three in Gladden, Matthew E., Neuroprosthetic Supersystems Architecture, pp. 113-45. Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-07-8 (print edition) and 978-1-944373-08-5 (ebook).

"Prosthetics: Sponsor." Johns Hopkins Applied Physics Laboratory. http://www.jhuapl.edu/prosthetics/program/sponsor.asp. Accessed December 5, 2016.

Proudfoot, Diane. "Software Immortals: Science or Faith?" In *Singularity Hypotheses*, edited by Amnon H. Eden, James H. Moor, Johnny H. Søraker, and Eric Steinhart, pp. 367-92. The Frontiers Collection. Springer Berlin Heidelberg, 2012.

Putnam, Hilary. *Reason, Truth and History*. Cambridge: Cambridge University Press, 1981.

Radvansky, Gabriel A. *Human Memory.* Second edition. New York: Routledge, 2016.

Ramirez, S., X. Liu, P.-A. Lin, J. Suh, M. Pignatelli, R.L. Redondo, T.J. Ryan, and S. Tonegawa. "Creating a False Memory in the Hippocampus." *Science* 341, no. 6144 (2013): 387-91.

Rao, R.P.N., A. Stocco, M. Bryan, D. Sarma, T.M. Youngquist, J. Wu, and C.S. Prat. "A direct brain-to-brain interface in humans." *PLoS ONE* 9, no. 11 (2014).

Rao, Umesh Hodeghatta, and Umesha Nayak. *The InfoSec Handbook*. New York: Apress, 2014.

Regalado, Antonio. "Engineering the perfect baby." *MIT Technology Review* 118, no. 3 (2015): 27-33.

Rehm, M., André, E., and Nakano, Y. "Some Pitfalls for Developing Enculturated Conversational Agents." In *Human-Computer Interaction: Ambient, Ubiquitous and Intelligent Interaction*, pp. 340-48. Lecture Notes in Computer Science 5612. Springer Berlin Heidelberg, 2009.

Rehm, M., Y. Nakano, E. André, T. Nishida, N. Bee, B. Endrass, M. Wissner, A.A. Lipi, and H. Huang, "From observation to simulation: generating culture-specific behavior for interactive systems." *AI & SOCIETY* vol. 24, no. 3 (2009): 267-80.

Reynolds, Dwight W., Christina M. Murray, and Robin E. Germany. "Device Therapy for Remote Patient Management." In *Electrical Diseases of the Heart*, edited by Ihor Gussak, Charles Antzelevitch, Arthur A. M. Wilde, Paul A. Friedman, Michael J. Ackerman, and Win-Kuang Shen, pp. 809-25. Springer London, 2008.

Robertazzi, Thomas G. *Networks and Grids: Technology and Theory*. Springer-Verlag New York, 2007.

Robinett, W. "The consequences of fully understanding the brain." In *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science*, edited by M.C. Roco and W.S. Bainbridge, pp. 166-70. National Science Foundation, 2002.

Roden, David. *Posthuman Life: Philosophy at the Edge of the Human*. Abingdon: Routledge, 2014.

Rodriguez, Ana Maria. *Autism Spectrum Disorders*. Minneapolis: Twenty-First Century Books, 2011.

Rohloff, Michael. "Framework and Reference for Architecture Design." In *AMCIS 2008 Proceedings*, 2008. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.231.8261&rep=rep1&type=pdf. Accessed October 21, 2015.

Rookes, Paul, and Jane Willson. *Perception: Theory, Development and Organisation.* London: Routledge, 2000.

Roosendaal, Arnold. "Implants and Human Rights, in Particular Bodily Integrity." In *Human ICT Implants: Technical, Legal and Ethical Considerations*, edited by Mark N. Gasson, Eleni Kosta, and Diana M. Bowman, pp. 81-96. Information Technology and Law Series 23. T. M. C. Asser Press, 2012.

Rosenbaum, David A. *Human Motor Control.* Second edition. Burlington, MA: Elsevier, 2010.

"An Ontology of Neuroprostheses as Instruments of 'Cyborgization': Portals to the Experience of Posthumanized Digital-Physical Worlds," Chapter Three in Gladden, Matthew E., Neuroprosthetic Supersystems Architecture, pp. 113-45. Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-07-8 (print edition) and 978-1-944373-08-5 (ebook).

Rotter, Pawel, Barbara Daskala, and Ramon Compañó. "Passive Human ICT Implants: Risks and Possible Solutions." In *Human ICT Implants: Technical, Legal and Ethical Considerations*, edited by Mark N. Gasson, Eleni Kosta, and Diana M. Bowman, pp. 55-62. Information Technology and Law Series 23. T. M. C. Asser Press, 2012.

Rowlands, Mark. *Can Animals Be Moral?* Oxford: Oxford University Press, 2012.

Royakkers, Lambèr, and Rinie van Est. "A literature review on new robotics: automation from love to war." *International journal of social robotics* 7, no. 5 (2015): 549-70.

Rozhok, Andrii. *Orientation and Navigation in Vertebrates.* Springer-Verlag Berlin Heidelberg, 2008.

Rugg, Michael D., Jeffrey D. Johnson, and Melina R. Uncapher. "Encoding and Retrieval in Episodic Memory: Insights from fMRI." In *The Wiley Handbook on the Cognitive Neuroscience of Memory*, edited by Donna Rose Addis, Morgan Barense, and Audrey Duarte, pp. 84-107. Malden, MA: John Wiley & Sons, 2015.

Rutherford, Andrew, Gerasimos Markopoulos, Davide Bruno, and Mirjam Brady-Van den Bos. "Long-Term Memory: Encoding to Retrieval." In *Cognitive Psychology*, second edition, edited by Nick Braisby and Angus Gellatly, pp. 229-65. Oxford: Oxford University Press, 2012.

Rutten, W. L. C., T. G. Ruardij, E. Marani, and B. H. Roelofsen. "Neural Networks on Chemically Patterned Electrode Arrays: Towards a Cultured Probe." In *Operative Neuromodulation*, edited by Damianos E. Sakas and Brian A. Simpson, pp. 547-54. Acta Neurochirurgica Supplements 97/2. Springer Vienna, 2007.

Rynes, Sara L., Barry Gerhart, and Kathleen A. Minette. "The importance of pay in employee motivation: Discrepancies between what people say and what they do." *Human Resource Management* 43, no. 4 (2004): 381-94.

Saha, S.K. *Introduction to Robotics.* New Delhi: Tata McGraw-Hill Publishing Company Limited, 2008.

Sakas, Damianos E., I. G. Panourias, B. A. Simpson, and E. S. Krames. "An Introduction to Operative Neuromodulation and Functional Neuroprosthetics, the New Frontiers of Clinical Neuroscience and Biotechnology." In *Operative Neuromodulation*, edited by Damianos E. Sakas and Brian A. Simpson, pp. 2-10. Acta Neurochirurgica Supplements 97/1. Springer Vienna, 2007.

Salvini, Pericle, Cecilia Laschi, and Paolo Dario. "From robotic tele-operation to tele-presence through natural interfaces." In *The First IEEE/RAS-EMBS International Conference on Biomedical Robotics and Biomechatronics, 2006. BioRob 2006*, pp. 408-13. IEEE, 2006.

Sanchez, Justin C. *Neuroprosthetics: Principles and Applications.* Boca Raton: CRC Press, 2016.

Sandberg, Anders. "Ethics of brain emulations." *Journal of Experimental & Theoretical Artificial Intelligence* 26, no. 3 (2014): 439-57.

Sandor, Christian, Martin Fuchs, Alvaro Cassinelli, Hao Li, Richard Newcombe, Goshiro Yamamoto, and Steven Feiner. "Breaking the Barriers to True Augmented Reality." arXiv preprint, *arXiv:1512.05471 [cs.HC]*, December 17, 2015. http://arxiv.org/abs/1512.05471. Accessed January 25, 2016.

Sasse, Martina Angela, Sacha Brostoff, and Dirk Weirich. "Transforming the 'weakest link' – a human/computer interaction approach to usable and effective security." *BT technology journal* 19, no. 3 (2001): 122-31.

Sayood, Khalid. *Introduction to Data Compression.* Waltham, MA: Morgan Kaufmann, 2012.

Sayrafian-Pour, K., W.-B. Yang, J. Hagedorn, J. Terrill, K. Yekeh Yazdandoost, and K. Hamaguchi. "Channel Models for Medical Implant Communication." *International Journal of Wireless Information Networks* 17, no. 3-4 (December 9, 2010): 105-12.

Schermer, Maartje. "The Mind and the Machine. On the Conceptual and Moral Implications of Brain-Machine Interaction." *NanoEthics* 3, no. 3 (December 1, 2009): 217-30.

Schwartz, Bennett L. *Memory: Foundations and Applications.* Second edition. Thousand Oaks, CA: SAGE Publications, Inc., 2014.

"Security Risk Assessment Framework for Medical Devices." Washington, DC: Medical Device Privacy Consortium, 2014.

Self-Organizing Networks (SON): Self-Planning, Self-Optimization and Self-Healing for GSM, UMTS, and LTE, edited by Juan Ramiro and Khalid Hamied. Chichester: John Wiley & Sons Ltd., 2012.

Sensory Evolution on the Threshold: Adaptations in Secondarily Aquatic Vertebrates, edited by J.G.M. Thewissen and Sirpa Nummela. Berkeley: University of California Press, 2008.

Settle-Murphy, Nancy M. *Leading Effective Virtual Teams: Overcoming Time and Distance to Achieve Exceptional Results*. Boca Raton: CRC Press, 2012.

Shahinpoor, Mohsen, Kwang J. Kim, and Mehran Mojarrad. *Artificial Muscles: Applications of Advanced Polymeric Nanocomposites*. Boca Raton: Taylor & Francis, 2007.

Shekhar, Sandhya. *Managing the Reality of Virtual Organizations*. Springer India, 2016.

Sherwood, Lauralee. *Fundamentals of Human Physiology.* Fourth edition. Belmont, CA: Brooks/Cole, 2012.

Shoniregun, Charles A., Kudakwashe Dube, and Fredrick Mtenzi. "Introduction to E-Healthcare Information Security." In *Electronic Healthcare Information Security*, pp. 1-27. Advances in Information Security 53. Springer US, 2010.

Siegel, Allan, and Hreday Sapru. *Essential Neuroscience*. Baltimore: Lippincott Williams & Wilkins, 2006.

Siewert, Charles. "Consciousness and Intentionality." *The Stanford Encyclopedia of Philosophy* (Fall 2011 Edition), edited by Edward N. Zalta. http://plato.stanford.edu/archives/fall2011/entries/consciousness-intentionality/.

Siewiorek, Daniel, and Robert Swarz. *Reliable Computer Systems: Design and Evaluation*. Second edition. Burlington: Digital Press, 1992.

Sloman, Aaron. "Some Requirements for Human-like Robots: Why the recent over-emphasis on embodiment has held up progress." In *Creating brain-like intelligence*, pp. 248-77. Springer Berlin Heidelberg, 2009.

Smith, C.U.M., *Biology of Sensory Systems*. Second edition. Chichester: John Wiley & Sons Ltd., 2008.

Smolensky, Paul. "The constituent structure of connectionist mental states: A reply to Fodor and Pylyshyn." *The Southern Journal of Philosophy* 26, no. S1 (1988): 137-61.

Snider, Greg S. "Cortical Computing with Memristive Nanodevices." *SciDAC Review* 10 (2008): 58-65.

Snyder, Allan W., Elaine Mulcahy, Janet L. Taylor, D. John Mitchell, Perminder Sachdev, and Simon C. Gandevia. "Savant-like skills exposed in normal people by suppressing the left fronto-temporal lobe." *Journal of integrative neuroscience* 2, no. 02 (2003): 149-58.

Snyder, Allan. "Explaining and inducing savant skills: privileged access to lower level, less-processed information." *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 364, no. 1522 (2009): 1399-1405.

Social Robots and the Future of Social Relations, edited by Johanna Seibt, Raul Hakli, and Marco Nørskov. Amsterdam: IOS Press, 2014.

Social Robots from a Human Perspective, edited by Jane Vincent, Sakari Taipale, Bartolomeo Sapio, Giuseppe Lugano, and Leopoldina Fortunati. Springer International Publishing, 2015.

Social Robots: Boundaries, Potential, Challenges, edited by Marco Nørskov. Farnham: Ashgate Publishing, 2016.

Sohl-Dickstein, Jascha, Santani Teng, Benjamin M. Gaub, Chris C. Rodgers, Crystal Li, Michael R. DeWeese, and Nicol S. Harper. "A device for human ultrasonic echolocation." *IEEE Transactions on Biomedical Engineering* 62, no. 6 (2015): 1526-34.

Sosinsky, Barrie. *Networking Bible*. Indianapolis: Wiley Publishing Inc., 2009.

Soussou, Walid V., and Theodore W. Berger. "Cognitive and Emotional Neuroprostheses." In *Brain-Computer Interfaces*, pp. 109-23. Springer Netherlands, 2008.

"Spinal Cord Stimulation." American Association of Neurological Surgeons, October 2008. http://www.aans.org/Patient%20Information/Conditions%20and%20Treatments/Spinal%20Cord%20Stimulation.aspx. Accessed December 8, 2016.

Spohrer, Jim. "NBICS (Nano-Bio-Info-Cogno-Socio) Convergence to Improve Human Performance: Opportunities and Challenges." In *Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science*, edited by M.C. Roco and W.S. Bainbridge, pp. 101-17. Arlington, VA: National Science Foundation, 2002.

Srinivasan, G. R. "Modeling the cosmic-ray-induced soft-error rate in integrated circuits: an overview." *IBM Journal of Research and Development* 40, no. 1 (1996): 77-89.

Stahl, B. C. "Responsible Computers? A Case for Ascribing Quasi-Responsibility to Computers Independent of Personhood or Agency." *Ethics and Information Technology* 8, no. 4 (2006): 205-13.

Stallings, William. *Cryptography and Network Security: Principles and Practice*. Seventh edition. Harlow: Pearson Education Limited, 2017.

Starr, Cecie, and Beverly McMillan. *Human Biology.* Eleventh edition. Boston: Cengage Learning, 2016.

Stelzer, Dirk. "Enterprise Architecture Principles: Literature Review and Research Directions." In *Service-Oriented Computing. ICSOC/ServiceWave 2009 Workshops*, pp. 12-21. Springer, 2010.

Stieglitz, Thomas. "Restoration of Neurological Functions by Neuroprosthetic Technologies: Future Prospects and Trends towards Micro-, Nano-, and Biohybrid Systems." In *Operative Neuromodulation*, edited by Damianos E. Sakas, Brian A. Simpson, and Elliot S. Krames, pp. 435-42. Acta Neurochirurgica Supplements 97/1. Springer Vienna, 2007.

Streib, James T. *Guide to Assembly Language: A Concise Introduction.* Springer-Verlag London Limited, 2011.

"Studies Find Disparities in Use of Deep Brain Stimulation." Parkinson's Disease Foundation, January 29, 2014. http://www.pdf.org/en/science_news/release/pr_1391019029. Accessed December 8, 2016.

Sundberg, Hakan P. "Building the Enterprise Architecture: A Bottom-Up Evolution?" In *Advances in Information Systems Development*, edited by Wita Wojtkowski, W. Gregory Wojtkowski, Jože Zupancic, Gabor Magyar, and Gabor Knapp, 287. Springer US, 2007.

"Surgeons Publish Study on Auditory Brainstem Implant Procedure." *The Hearing Review*, May 22, 2015. http://www.hearingreview.com/2015/05/surgeons-publish-study-auditory-brainstem-implant-procedure/. Accessed December 8, 2016.

Synaesthesia: Theoretical, artistic and scientific foundations, edited by María José de Córdoba Serrano, Dina Riccò, and Sean A. Day. Granada: International Foundation Artecittà Publishing, 2014.

Szoldra, P. "The government's top scientists have a plan to make military cyborgs." *Tech Insider*, January 22, 2016. http://www.techinsider.io/darpa-neural-interface-2016-1. Accessed May 6, 2016.

Talan, J. "DARPA: On the Hunt for Neuroprosthetics to Enhance Memory." *Neurology Today* 14, no. 20 (2014): 8-10.

Tang, Hao, Yun Fu, Jilin Tu, Mark Hasegawa-Johnson, and Thomas S. Huang. "Humanoid audio–visual avatar with emotive text-to-speech synthesis." *IEEE Transactions on multimedia* 10, no. 6 (2008): 969-81.

Targeted Muscle Reinnervation: A Neural Interface for Artificial Limbs, edited by Todd A. Kuiken, Aimee E. Schultz Feuser, and Ann K. Barlow. Boca Raton: CRC Press, 2014.

Tarín, C., L. Traver, P. Martí, and N. Cardona. "Wireless Communication Systems from the Perspective of Implantable Sensor Networks for Neural Signal Monitoring." In *Wireless Technology*, edited by S. Powell and J.P. Shim, pp. 177-201. Lecture Notes in Electrical Engineering 44. Springer US, 2009.

Taylor, N. R., and J. G. Taylor. "The Neural Networks for Language in the Brain: Creating LAD." In *Computational Models for Neuroscience*, edited by Robert Hecht-Nielsen and Thomas McKenna, pp. 245-65. Springer London, 2003.

Taylor, Annette Kujawski, "Hyperthymesia." In *Encyclopedia of Human Memory*, edited by Annette Kujawski Taylor, pp. 547-50. Santa Barbara: Greenwood, 2013.

Taylor, Dawn M. "Functional Electrical Stimulation and Rehabilitation Applications of BCIs." In *Brain-Computer Interfaces*, pp. 81-94. Springer Netherlands, 2008.

Taylor, Dawn M., Stephen I. Helms Tillery, and Andrew B. Schwartz. "Direct cortical control of 3D neuroprosthetic devices." *Science* 296, no. 5574 (2002): 1829-32.

Teng, Santani, and David Whitney. "The acuity of echolocation: spatial resolution in the sighted compared to expert performance." *Journal of visual impairment & blindness* 105, no. 1 (2011): 20-32.

Tennison, Michael N., and Jonathan D. Moreno. "Neuroscience, Ethics, and National Security: The State of the Art." *PLOS Biology*, March 20, 2012. http://dx.doi.org/10.1371/journal.pbio.1001289. Accessed December 5, 2016.

Thanos, Solon, P. Heiduschka, and T. Stupp. "Implantable Visual Prostheses." In *Operative Neuromodulation*, edited by Damianos E. Sakas and Brian A. Simpson, pp. 465-72. Acta Neurochirurgica Supplements 97/2. Springer Vienna, 2007.

Thornton, Stephanie. *Understanding Human Development: Biological, Social and Psychological Processes from Conception to Adult Life*. New York: Palgrave Macmillan, 2008.

Thorpe, Julie, Paul C. van Oorschot, and Anil Somayaji. "Pass-thoughts: authenticating with our minds." In *Proceedings of the 2005 Workshop on New Security Paradigms*, pp. 45-56. ACM, 2005.

TOGAF® Version 9.1. Berkshire: The Open Group, 2011.

Tomas, David. "Feedback and Cybernetics: Reimaging the Body in the Age of the Cyborg." In *Cyberspace, Cyberbodies, Cyberpunk: Cultures of Technological Embodiment*, edited by Mike Featherstone and Roger Burrows, pp. 21-43. London: SAGE Publications, 1995.

Transcranial Magnetic Stimulation in Clinical Psychiatry, edited by Mark S. George and Robert H. Belmaker. Washington, DC: American Psychiatric Publishing, Inc., 2007.

Treffert, Darold A. "Accidental Genius." *Scientific American* 311, no. 2 (2014): 52-57.

Treffert, Darold A. "The savant syndrome: an extraordinary condition. A synopsis: past, present, future." *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 364, no. 1522 (2009): 1351-57.

Troyk, Philip R., and Stuart F. Cogan. "Sensory Neural Prostheses." In *Neural Engineering*, edited by Bin He, pp. 1-48. Bioelectric Engineering. Springer US, 2005.

Turner, Patrick, John Gøtze, and Peter Bernus. "Architecting the Firm – Coherency and Consistency in Managing the Enterprise." In *On the Move to Meaningful Internet Systems: OTM 2009 Workshops*, edited by Robert Meersman, Pilar Herrero, and Tharam Dillon, pp. 162-71. Lecture Notes in Computer Science 5872. Springer Berlin Heidelberg, 2009.

Upper Motor Neurone Syndrome and Spasticity: Clinical Management and Neurophysiology, second edition, edited by Michael P. Barnes and Garth R. Johnson. Cambridge: Cambridge University Press, 2008.

Van den Berg, Bibi. "Pieces of Me: On Identity and Information and Communications Technology Implants." In *Human ICT Implants: Technical, Legal and Ethical Considerations*, edited by Mark N. Gasson, Eleni Kosta, and Diana M. Bowman, pp. 159-73. Information Technology and Law Series 23. T. M. C. Asser Press, 2012.

Van der Raadt, Bas and Hans van Vliet. "Assessing the Efficiency of the Enterprise Architecture Function." In *Advances in Enterprise Engineering II*, edited by Erik Proper, Frank Harmsen, and Jan L. G. Dietz, 63. Lecture Notes in Business Information Processing 28. Springer Berlin Heidelberg, 2009.

Van der Torre, Leendert, Marc M. Lankhorst, Hugo ter Doest, Jan T. P. Campschroer, and Farhad Arbab. "Landscape Maps for Enterprise Architectures." In *Advanced Information Systems Engineering*, edited by Eric Dubois and Klaus Pohl. Lecture Notes in Computer Science 4001. Springer Berlin Heidelberg, 2006.

Van Drongelen, Wim, Hyong C. Lee, and Kurt E. Hecox. "Seizure Prediction in Epilepsy." In *Neural Engineering*, edited by Bin He, pp. 389-419. Bioelectric Engineering. Springer US, 2005.

Vänni, Kimmo J., and Annina K. Korpela. "Role of Social Robotics in Supporting Employees and Advancing Productivity." In *Social Robotics*, pp. 674-83. Springer International Publishing, 2015.

Versace, Massimiliano, and Ben Chandler. "The Brain of a New Machine." *IEEE spectrum* 47, no. 12 (2010): 30-37.

Vinciarelli, A., M. Pantic, D. Heylen, C. Pelachaud, I. Poggi, F. D'Errico, and M. Schröder. "Bridging the Gap between Social Animal and Unsocial Machine: A survey of Social Signal Processing." *IEEE Transactions on Affective Computing* 3:1 (January-March 2012): 69-87.

Viola, M. V., and Aristides A. Patrinos. "A Neuroprosthesis for Restoring Sight." In *Operative Neuromodulation*, edited by Damianos E. Sakas and Brian A. Simpson, pp. 481-86. Acta Neurochirurgica Supplements 97/2. Springer Vienna, 2007.

Virtual Organizations: Systems and Practices, edited by Luis M. Camarinha-Matos, Hamideh Afsarmanesh, and Martin Ollus. Boston: Springer Science+Business Media, 2005.

Wallach, Wendell, and Colin Allen. *Moral machines: Teaching robots right from wrong.* Oxford University Press, 2008.

Warwick, K. "The Cyborg Revolution." *Nanoethics* 8 (2014): 263-73.

Warwick, K., and M. Gasson. "Implantable Computing." In *Digital Human Modeling*, edited by Y. Cai, pp. 1-16. Lecture Notes in Computer Science 4650. Berlin/Heidelberg: Springer, 2008.

Weiland, James D., Wentai Liu, and Mark S. Humayun. "Retinal Prosthesis." *Annual Review of Biomedical Engineering* 7, no. 1 (2005): 361-401.

Weinberger, Sharon. "Pentagon to Merge Next-Gen Binoculars with Soldiers' Brains." *Wired*, May 1, 2007. https://www.wired.com/2007/05/binoculars/. Accessed December 5, 2016.

Weiss, Simon, and Robert Winter. "Development of Measurement Items for the Institutionalization of Enterprise Architecture Management in Organizations." In *Trends in Enterprise Architecture Research and Practice-Driven Research on Enterprise Transformation*, edited by Stephan Aier, Mathias Ekstedt, Florian Matthes, Erik Proper, and Jorge L. Sanz, pp. 268-83. Lecture Notes in Business Information Processing 131. Springer Berlin Heidelberg, 2012.

Wells, M.J. *Octopus: Physiology and Behaviour of an Advanced Invertebrate*. Springer Netherlands, 1978.

Westlake, Philip R. "The possibilities of neural holographic processes within the brain." *Biological Cybernetics* 7, no. 4 (1970): 129-53.

White, Stephen E. "Brave new world: Neurowarfare and the limits of international humanitarian law." *Cornell International Law Journal* 41 (2008): 177.

Widge, A.S., C.T. Moritz, and Y. Matsuoka. "Direct Neural Control of Anatomically Correct Robotic Hands." In *Brain-Computer Interfaces*, edited by D.S. Tan and A. Nijholt, pp. 105-19. Human-Computer Interaction Series. London: Springer, 2010.

Wiener, Norbert. *Cybernetics: Or Control and Communication in the Animal and the Machine*, second edition. Cambridge, MA: The MIT Press, 1961. [Quid Pro ebook edition for Kindle, 2015.]

Wilkinson, Jeff, and Scott Hareland. "A cautionary tale of soft errors induced by SRAM packaging materials." *IEEE Transactions on Device and Materials Reliability* 5, no. 3 (2005): 428-33.

Williams, Theodore J., and Hong Li. "PERA and GERAM – Enterprise Reference Architectures in Enterprise Integration." In *Information Infrastructure Systems for Manufacturing II*, edited by John J. Mills and Fumihiko Kimura, pp. 3-30. IFIP – The International Federation for Information Processing 16. Springer US, 1999.

Wilson, Margaret. "Six views of embodied cognition." *Psychonomic bulletin & review* 9, no. 4 (2002): 625-36.

Wise, Kensall D., Amir M. Sodagar, Ying Yao, Mayurachat Ning Gulari, Gayatri E. Perlin, and Khalil Najafi. "Microelectrodes, microelectronics, and implantable neural microsystems." *Proceedings of the IEEE* 96, no. 7 (2008): 1184-1202.

Wise, Kensall D., D. J. Anderson, J. F. Hetke, D. R. Kipke, and K. Najafi. "Wireless implantable microsystems: high-density electronic interfaces to the nervous system." *Proceedings of the IEEE* 92, no. 1 (2004): 76-97.

Woisetschläger, David M. "Consumer Perceptions of Automated Driving Technologies: An Examination of Use Cases and Branding Strategies." In *Autonomous Driving*, pp. 687-706. Springer Berlin Heidelberg, 2016.

Wolf-Meyer, Matthew. "Fantasies of extremes: Sports, war and the science of sleep." *BioSocieties* 4, no. 2 (2009): 257-71.

Wooldridge, M., and N. R. Jennings. "Intelligent agents: Theory and practice." *The Knowledge Engineering Review*, 10(2) (1995): 115-52.

Yampolskiy, Roman V. "The Universe of Minds." arXiv preprint, *arXiv:1410.0369 [cs.AI]*, October 1, 2014. http://arxiv.org/abs/1410.0369. Accessed January 25, 2016.

Yonck, Richard. "Toward a standard metric of machine intelligence." *World Future Review* 4, no. 2 (2012): 61-70.

Zebda, Abdelkader, S. Cosnier, J.-P. Alcaraz, M. Holzinger, A. Le Goff, C. Gondran, F. Boucher, F. Giroud, K. Gorgy, H. Lamraoui, and P. Cinquin. "Single glucose biofuel cells implanted in rats power electronic devices." *Scientific Reports* 3, article 1516 (2013).

Zhao, QiBin, LiQing Zhang, and Andrzej Cichocki. "EEG-Based Asynchronous BCI Control of a Car in 3D Virtual Reality Environments." *Chinese Science Bulletin* 54, no. 1 (January 11, 2009): 78-87.

Zofi, Yael. *A Manager's Guide to Virtual Teams.* New York: American Management Association, 2012.

Zullo, Letizia, German Sumbre, Claudio Agnisola, Tamar Flash, and Binyamin Hochner. "Non-somatotopic organization of the higher motor centers in octopus." *Current Biology* 19, no. 19 (2009): 1632-36.

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