Chapter One

An Introduction to Advanced Neuroprosthetics

Abstract. This text presents an introduction to neuroprosthetic devices and systems that explores both the state of the art of sensory, motor, and cognitive neuroprostheses that are currently in use as well as more sophisticated kinds of neuroprosthetic technologies that are being actively pursued or that are expected to be developed in the future. This overview takes us from the contemporary world of neuroprostheses that have been designed primarily for purposes of therapeutic treatment of medical disorders and the restoration of natural human abilities lost due to illness or injury to an emerging future world in which neuroprosthetic devices offer the possibility of augmenting and transforming the capacities of their users in such a way that they can perhaps best be described as 'posthumanizing' technologies.

I. Overview of current neuroprosthetic devices

The integration of human beings with computers at both the physical and cognitive levels is growing ever deeper, as new technologies are developed and the daily routines of our human existence adapt to incorporate these new means of experiencing and shaping reality. Traditionally, **human-computer interaction (HCI)** has relied on tools that are external to the human body, such as keyboards, mice, computer screens, and speakers. In recent years, the emergence of mobile and wearable technologies such as smartphones, smartwatches, and virtual reality headsets has created a new range of devices that are more intimately connected with the bodies of their human users. But for a growing population of persons, computerized information systems are no longer technologies that simply exist outside of – or even on the surface of – their bodies; for these persons, computing technologies have passed through the boundaries of the human body and have come to exist and to operate within their physical being. For example, an increasing number of human beings now house within their bodies implantable computers that are active and functioning continually as those persons go about their everyday activities. Such implantable computers often form key components of implantable medical devices (IMDs) such as defibrillators, pacemakers, deep brain stimulators, retinal and cochlear implants, or diagnostic devices such as body area

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networks (BANs) or body sensor networks (BSNs). Some of the more sophisticated forms of implantable RFID transponders also function as implantable computers.[1] Such implantable computers are increasingly serving as sites for the reception, generation, storage, processing, and transmission of large quantities of highly sensitive information[2] regarding almost every aspect of the lives of their human hosts, including their hosts' everyday interactions with the environment (including interactions with other human beings), their internal biological processes, and even their cognitive activity.

One kind of computer that becomes linked with a particular human being's organism in an especially powerful and intimate way is a **neuroprosthetic device** that is integrated directly into the body's neural circuitry.[3] A neuroprosthetic device may either be physically inserted into the brain, as in the case of many kinds of brain implants already in use, or it could potentially surround the brain, as in the case of a full cyborg body of the sort envisioned by some researchers and futurologists.[4] Neuroprosthetic devices increasingly operate in rich and complex biocybernetic and neurocybernetic control loops with the body and mind of their human host, allowing the host's cognitive activity to be detected, analyzed, and interpreted for use in exercising real-time control over computers or robotic devices.[5]

The terminology used to describe such devices is still quite fluid and not always precise, as it is evolving rapidly alongside the underlying technologies.

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[1] See Gasson et al., "Human ICT Implants: From Invasive to Pervasive" (2012), and Gasson, "ICT Implants" (2008).

[2] See Kosta & Bowman, "Implanting Implications: Data Protection Challenges Arising from the Use of Human ICT Implants" (2012); Li et al., "Advances and Challenges in Body Area Network" (2011); and Rotter & Gasson, "Implantable Medical Devices: Privacy and Security Concerns" (2012).

[3] For a discussion of circuit models as they apply to neural information processing, see Ma et al., "Circuit Models for Neural Information Processing" (2005). For the challenges involved with designing electrodes and other implantable electronic devices or structures that can create a sustainable interface with individual neurons, see Passeraub & Thakor, "Interfacing Neural Tissue with Microsystems" (2005). For a discussion of different technologies used to interface electronic systems with peripheral nerves (e.g., cuff, book, or helix electrodes) or cortical neurons (e.g., needle arrays), see Koch, "Neural Prostheses and Biomedical Microsystems in Neurological Rehabilitation" (2007). Emerging technologies such as optogenetics used to modulate neuronal firing may make it possible to solve (or avoid) some problems relating to biocompatibility and the degradation of tissues and electrodes experienced with conventional implanted electrode systems; see Humphreys et al., "Long Term Modulation and Control of Neuronal Firing in Excitable Tissue Using Optogenetics" (2011).

[4] See Lebedev, "Brain-Machine Interfaces: An Overview" (2014), p. 99.

[5] See Fairclough, "Physiological Computing: Interfacing with the Human Nervous System" (2010), and Park et al., "The Future of Neural Interface Technology" (2009).

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Lebedev notes that while particular terms may be more appropriate in specific circumstances, neuroprosthetic devices and systems are often described interchangeably as “brain-machine interfaces” (or BMIs), “neural prostheses, brain-computer interfaces (BCIs), neural interfaces, mind-machine interfaces and brain implants.”[6] The design and use of such devices is sometimes understood as a subfield of operative neuromodulation, which involves “altering electrically or chemically the signal transmission in the nervous system by implanted devices in order to excite, inhibit or tune the activities of neurons or neural networks” – something that is done typically (at least, at present) to produce therapeutic effects.[7] Drawing on definitions offered by Lebedev[8] and others, for the purposes of this text we can define a neuroprosthetic device as **a technological device that is integrated into the neural circuitry of a human being**. Such a definition is intentionally broad; at the same time, it is specific enough to exclude some kinds of devices that might be considered ‘neuroprosthetic devices’ by other authors writing in different contexts. We can note some key implications of our definition as it will be employed in this text:

- A neuroprosthetic device does not need to be physically implanted within the body of a human host; in principle, it could function outside of its host’s body (e.g., as a wearable device).
- The neuroprosthetic device must, however, be “integrated into” the neural circuitry of its human host. This requirement for integration entails a relatively rich and stable systematic connection between the device and some neurons within the host’s body. An fMRI machine, for example, would thus typically not qualify as a ‘neuroprosthetic device,’ because despite the large amount of information that it generates regarding the neural activity of its host – and the effect of its magnetic field on the brain – it is not “integrated into” the host’s neural circuitry.
- In order for a neuroprosthetic device to be integrated into the neural circuitry of its human host, it is not sufficient for the device to physically adjoin particular neurons or even to be completely surrounded by the host’s neurons; rather there must be some functional interaction between the device and neurons in the host’s body. Such interaction does not need to be bidirectional: a retinal prosthesis, for example, might generate and transmit an electrochemical stimulus that

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[6] See Lebedev (2014), p. 99.

[7] See Sakas et al., “An Introduction to Neural Networks Surgery, a Field of Neuromodulation Which Is Based on Advances in Neural Networks Science and Digitised Brain Imaging” (2007).

[8] See Lebedev (2014) and Gladden, “Enterprise Architecture for Neurocybernetically Augmented Organizational Systems: The Impact of Posthuman Neuroprosthetics on the Creation of Strategic, Structural, Functional, Technological, and Sociocultural Alignment” (2016).

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affects adjacent neurons while not being able to receive any stimulus from those neurons in return.

- A neuroprosthetic device does not need to be connected to neurons in its host's *brain*. While some existing kinds of neuroprosthetic devices indeed possess a physical interface with interneurons found in the gray matter of the human brain, a neuroprosthetic device might instead be connected to sensory or motor neurons located in limbs, sensory organs, or other parts of the body.
- A neuroprosthetic device does not need to be electronic in nature. Ongoing developments in fields such as genetic engineering, synthetic biology, bionanotechnology, and biomolecular computing are opening the door to the creation of neuroprosthetic devices that are partially or wholly composed of biological material (perhaps based on the DNA of the device's host) or other components.[9] It must, however, be a 'device' that has been developed through the use of some specific technology; in the absence of specific augmentations or modifications, a limb or organ that has simply been transplanted from another human being into its new human host would generally not qualify as a neuroprosthetic device.

A. Neuroprosthetic devices categorized by function

Existing kinds of neuroprosthetic devices have been categorized in different ways.[10] For example, a neuroprosthetic device can be classified based on the nature of its interface with the brain's neural circuitry as either **sensory**, **motor**, **bidirectional sensorimotor**, or **cognitive**.[11] We can consider each of these types of devices in turn.

1. Sensory neuroprostheses

A sensory neuroprosthesis is a neuroprosthetic device whose function is to present sense data to the mind of the device's human host.[12] Typical kinds

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[9] For a hybrid biological-electronic interface device (or 'cultured probe') that includes a network of cultured neurons on a planar substrate, see Rutten et al., "Neural Networks on Chemically Patterned Electrode Arrays: Towards a Cultured Probe" (2007). As Rutten et al. note, such a cultured neural network would not only serve as a link between the interface's electronic components and natural neurons within the host's body but could potentially carry out its own specialized information-processing functions. Hybrid biological-electronic interface devices are also discussed in Stieglitz, "Restoration of Neurological Functions by Neuroprosthetic Technologies: Future Prospects and Trends towards Micro-, Nano-, and Biohybrid Systems" (2007).

[10] See Gladden, "Neural Implants as Gateways to Digital-Physical Ecosystems and Posthuman Socioeconomic Interaction" (2016).

[11] See Lebedev (2014).

[12] See Lebedev (2014) and Troyk & Cogan, "Sensory Neural Prostheses" (2005).

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of sensory neuroprostheses already in use include cochlear implants, auditory brainstem implants,[13] and retinal prostheses.[14]

Sensory neuroprostheses may participate in different stages of a human mind's process of acquiring and perceiving sensory information. Some sensory neuroprostheses perform, participate in, or support the acquisition of raw sense data from distal stimuli. For example, a retinal prosthesis that registers the arrival of photons from the external environment and then electrically stimulates its host's natural biological retinal ganglion cells is filling such a role.

Other sensory neuroprostheses may perform the function of transmitting, translating, or transducing electrochemical signals bearing sensory information that are already present within their host's body. For example, if the retina of a human subject is still intact but part of the attached optic nerve has been damaged, a sensory neuroprosthesis could replace a portion of the optic nerve in performing the task of carrying signals from the retina to the brain. Alternatively, a sensory neuroprosthesis could be used to translate sense data from one sensory modality to another:[15] for example, auditory sense data received by hair cells in the inner ear or by a cochlear implant could be translated by the neuroprosthetic device into signals that are supplied to the optic nerve, thereby causing the incoming sounds not to be 'heard' by its host through the sensory modality of hearing but instead to be 'seen' through the sensory modality of vision – with the sounds perhaps appearing as patterns of light within a small portion of the host's field of vision, thereby creating a form of visual augmented reality.

Yet other kinds of sensory neuroprostheses might directly stimulate portions of the brain to create a particular sensory experience. For example, in the case of a human being whose optic nerve is destroyed or absent, a neuroprosthetic implant that is interconnected with neurons of its host's lateral geniculate nucleus or visual cortex could – by directly stimulating those areas – potentially cause the hostmind to experience visual phenomena that were

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[13] Regarding cochlear implants and auditory brainstem implants, see Dormer, "Implantable electronic otologic devices for hearing rehabilitation" (2003); Cervera-Paz et al., "Auditory Brainstem Implants: Past, Present and Future Prospects" (2007); Bostrom & Sandberg, "Cognitive Enhancement: Methods, Ethics, Regulatory Challenges" (2009), p. 321; Gasson et al. (2012); Hochmair, "Cochlear Implants: Facts" (2013), and Ochsner et al., "Human, non-human, and beyond: cochlear implants in socio-technological environments" (2015).

[14] For retinal prostheses, see Weiland et al., "Retinal Prosthesis" (2005); Linsenmeier, "Retinal Bioengineering" (2005); and Viola & Patrinos, "A Neuroprosthesis for Restoring Sight" (2007).

[15] This possibility was foreseen by cyberneticists as early as the 1940s. See Wiener, *Cybernetics: Or Control and Communication in the Animal and the Machine* (1961), loc. 2784ff, and Lebedev (2014), p. 106.

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not caused by any stimuli or signals present in the retina or optic nerve and which may not correspond to any distal stimuli existing in the external environment.[16] Data transmitted wirelessly to such an implant from an external computer could allow the host to experience either sense data corresponding to the 'real' environment existing outside the host's body or corresponding to some entirely 'virtual' environment whose characteristics are created and maintained by software within the computer. In all of these cases, a common trait is the fact that sensory neuroprosthetic devices are helping to present sense data to the mind of the devices' human host.

2. Motor neuroprostheses

Motor neuroprostheses, conversely, are devices that convey motor instructions – typically either from their human host's brain or from the device's own computer that is acting as a surrogate for the host's brain – to some organ, device, or system within or outside of the host's body for physical actuation.[17] Devices of this sort are already being used to fill a wide range of roles in treating diverse medical conditions and providing therapeutic benefits to many people around the world. For example, motor neuroprostheses are capable of detecting and interpreting their host's thoughts in order to allow the host to steer a wheelchair or guide a cursor around a computer screen.[18] They can provide life-altering benefits as the only means of communication with the outside world for locked-in patients who are completely paralyzed yet fully conscious, including those suffering from ALS, stroke, or traumatic brain injury.[19] They are also used to control internal bodily actions – for example, to restore bladder function after spinal cord injury, eliminate the need for an external ventilator in severely paralyzed individuals, or stimulate nerves that coordinate breathing and swallowing reflexes in order treat sleep apnea or facilitate swallowing after a stroke.[20] Motor neuroprostheses can also potentially be used to predict[21] or stop[22] epileptic seizures. They can

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[16] For the possibility of visual cortical implants, see Thanos et al., "Implantable Visual Prostheses" (2007).

[17] See Lebedev (2014) and Patil & Turner, "The Development of Brain-Machine Interface Neuroprosthetic Devices" (2008).

[18] See Edlinger et al., "Brain Computer Interface" (2011); Lebedev (2014); Merkel et al., "Central Neural Prostheses" (2007); and Widge et al., "Direct Neural Control of Anatomically Correct Robotic Hands" (2010).

[19] See Donchin & Arbel, "P300 Based Brain Computer Interfaces: A Progress Report" (2009).

[20] See Taylor, "Functional Electrical Stimulation and Rehabilitation Applications of BCIs" (2008).

[21] For the use of EEG-based systems for this purpose, see Drongelen et al., "Seizure Prediction in Epilepsy" (2005).

[22] See Fountas & Smith, "A Novel Closed-Loop Stimulation System in the Control of Focal, Medically Refractory Epilepsy" (2007).

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be used for functional electrical stimulation (FES) to restore muscle functionality to individuals suffering from paralysis[23] (either as a permanent assistive technology or temporary rehabilitative tool[24]), to treat central hypoventilation syndrome,[25] and for neurally augmented sexual function (NASF) to restore or improve sexual function in both male and female subjects.[26] Meanwhile, the use of BCI devices for vagus nerve stimulation (VNS) is being explored or considered to treat conditions such as Alzheimer's disease, anxiety disorders, bulimia, addictions, and narcolepsy.[27] Nontherapeutic applications of motor brain-computer interface (BCI) technologies have included, for example, the use of an EEG-based BCI to allow its human operator to drive a car in a 3D virtual reality environment.[28]

Some motor neuroprostheses are implanted in or interface with neurons in their host's brain, detecting neuronal activity that relates to a conscious volition or unconscious motor instruction and translating that activity into an output stimulus or signal produced by the device that activates or informs the functioning of transmission mechanisms that carry instructions to the motor plants or effectors that ultimately manifest the motor action. Other motor neuroprostheses directly perform the work of transmitting such instruction-bearing stimuli to a motor plant or effector (in the human organism, typically via a neuroeffector junction); still others receive and interpret such instructions and then execute the intended action through control of a motor plant, motor organ, or effector. Technologies that can be used to detect intent manifested within a human organism include electroencephalography (EEG), electrocorticography (ECoG), recordings of local field potentials (LFPs), and recordings of single-neuron action potentials,[29] as well as functional near infrared spectroscopy (fNIR).[30] Each technology has its unique

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[23] See Durand et al., "Electrical Stimulation of the Neuromuscular System" (2005), and Moxon, "Neurorobotics" (2005).

[24] See Masani & Popovic, "Functional Electrical Stimulation in Rehabilitation and Neurorehabilitation" (2011).

[25] See Taira & Hori, "Diaphragm Pacing with a Spinal Cord Stimulator: Current State and Future Directions" (2007).

[26] See Meloy, "Neurally Augmented Sexual Function" (2007).

[27] See Ansari et al., "Vagus Nerve Stimulation: Indications and Limitations" (2007).

[28] See Zhao et al., "EEG-Based Asynchronous BCI Control of a Car in 3D Virtual Reality Environments" (2009).

[29] See Principe & McFarland, "BMI/BCI Modeling and Signal Processing" (2008).

[30] See Ayaz et al., "Assessment of Cognitive Neural Correlates for a Functional Near Infrared-Based Brain Computer Interface System" (2009).

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strengths and weaknesses; for example, single-neuron recording is more invasive than EEG but less likely to be affected by artifacts from skin and muscle activity.[31]

3. Bidirectional sensorimotor neuroprostheses

Bidirectional sensorimotor neuroprostheses combine sensory and motor neuroprostheses in a single device that both provides sense data to the device's human host and receives instructions from the host that control the movement or other operation of the device. Some kinds of advanced prosthetic limbs are bidirectional sensorimotor neuroprosthetics: for example, an artificial hand may not only allow its human host to control the motion of the hand's fingers simply by willing such movements, but it may also provide the host with the ability to feel an object grasped within the hand and to sense how much pressure is being generated from the hand's contact with the object.[32]

Although most contemporary VR video game systems do not satisfy the definition of 'neuroprostheses' offered here (insofar as they do not directly integrate with a player's neural circuitry), systems that allow a player to control his or her action in a virtual game-world by motions of his or her real-world body (e.g., registered using motion-detecting sensors) and which then provide through the VR headset immediate visual and auditory feedback about the way in which the player's action has changed the game-world offer an example of the kind of intense biocybernetic feedback cycle that can be generated using bidirectional sensorimotor technologies.[33]

4. Cognitive neuroprostheses

A cognitive neuroprosthetic device participates in or supplements processes that are internal to the mind of its human host and which do not directly involve either sensory or motor organs (although the processes may receive input from or transmit output to such organs). Such neuroprosthetic devices may participate in cognitive processes and phenomena such as

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[31] See Miller & Ojemann, "A Simple, Spectral-Change Based, Electrocorticographic Brain–Computer Interface" (2009).

[32] See Hoffmann & Micera, "Introduction to Neuroprosthetics" (2011), pp. 792-93.

[33] See Gladden, "Cybershells, Shapeshifting, and Neuroprosthetics: Video Games as Tools for Posthuman 'Body Schema (Re)Engineering'" (2015).

memory, imagination,[34] emotion,[35] belief, identity,[36] agency, attentiveness, consciousness,[37] and conscience.

The development of such technologies for use in human beings is still in its earliest stages. Although not the primary purpose for which the devices were designed, effects relating to creativity and one's sense of authenticity and agency have been reported in patients utilizing neuroprosthetic devices for deep brain stimulation.[38] Mnemoprosthetic devices that allow the creation or alteration of memories by manipulating the brain's natural mechanisms for the storage of memories have been experimentally tested in mice[39] and in principle could potentially be employed with the human brain, as well. However, such technologies currently fall far short of allowing the implantation of complex, content-rich memories into a mind or allowing the precise and detailed editing of existing memories.[40] Indeed, deep mysteries exist regarding the mechanisms by which long-term memories are created, stored, and retrieved in the human mind, and divergent theories have been proposed to explain the functioning of such systems.[41] As neuroscience continues to advance and competing theories are either confirmed or rejected, we will learn more about the kinds of cognitive neuroprosthetic devices that theoretically can or cannot be created and successfully integrated into the neural circuitry and functioning of a human mind. (And conversely, the ability or inability to

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[34] See Cosgrove, "Session 6: Neuroscience, brain, and behavior V: Deep brain stimulation" (2004), and Gasson, "Human ICT Implants: From Restorative Application to Human Enhancement" (2012).

[35] For the possibility of developing emotional neuroprostheses, see Soussou & Berger, "Cognitive and Emotional Neuroprostheses" (2008); Hatfield et al., "Brain Processes and Neurofeedback for Performance Enhancement of Precision Motor Behavior" (2009); Kraemer, "Me, Myself and My Brain Implant: Deep Brain Stimulation Raises Questions of Personal Authenticity and Alienation" (2011); and McGee, "Bioelectronics and Implanted Devices" (2008), p. 217.

[36] See Kraemer (2011) and Van den Berg, "Pieces of Me: On Identity and Information and Communications Technology Implants" (2012).

[37] For the possibility of neuroprosthetic devices relating to sleep, see Claussen & Hofmann, "Sleep, Neuroengineering and Dynamics" (2012), and Kourany, "Human Enhancement: Making the Debate More Productive" (2013), pp. 992-93.

[38] See Kraemer (2011).

[39] See Han et al., "Selective Erasure of a Fear Memory" (2009); Josselyn, "Continuing the Search for the Engram: Examining the Mechanism of Fear Memories" (2010); and Ramirez et al., "Creating a False Memory in the Hippocampus" (2013).

[40] For questions about the extent to which technological devices that directly store memories can ever become a part of the human mind, see Clowes, "The Cognitive Integration of E-Memory" (2013).

[41] See, for example, Dudai, "The Neurobiology of Consolidations, Or, How Stable Is the Engram?" (2004).

successfully develop and implement particular kinds of neuroprosthetic devices may shed light on whether particular proposed brain theories are correct or incorrect.) For example, if holographic brain models[42] were found to be correct, it might largely rule out the possibility of constructing neuroprosthetic devices that can create or alter a complex long-term memory simply by manipulating a modest number of neurons in a particular region of the brain.

B. Neuroprosthetic devices categorized by purpose: therapy vs. enhancement

In addition to categorizing neuroprosthetic devices according to their function (i.e., as sensory, motor, bidirectional, or cognitive), such devices may also be categorized according to their purpose. For example, some neuroprosthetic devices are used for purposes of therapeutic **restoration**, to restore abilities that have been lost by a human being due to illness or injury. Other neuroprosthetic devices do not directly treat a medical condition but are instead used for purposes of **diagnosis**, to gather information about the condition of their human host and allow medical decisions to be made. Still other neuroprosthetic devices may be used for purposes of **identification**, to verify the identity of the device's human host, allow his or her whereabouts or activities to be tracked, or allow him or her access to some restricted area or resource.[43] Finally, some neuroprosthetic devices are designed for purposes of human **enhancement**: such devices augment, modify, or replace the sensory, motor, or cognitive abilities of their human host, allowing him or her to experience phenomena or perform actions that are not possible for the minds and bodies of natural, unmodified human beings.[44]

C. Neuroprosthetic devices categorized by physical location: implant vs. prosthesis

Neuroprosthetic devices may alternatively be categorized according to their relationship with the body of their human host.[45] In this text, we use the word '**implant**' to describe a neuroprosthetic device that is surgically inserted into the body of its human host and which remains within the host's body

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[42] Such models have been described, e.g., in Longuet-Higgins, "Holographic Model of Temporal Recall" (1968); Westlake, "The possibilities of neural holographic processes within the brain" (1970); Pribram, "Prolegomenon for a Holonomic Brain Theory" (1990); and Pribram & Meade, "Conscious Awareness: Processing in the Synaptodendritic Web – The Correlation of Neuron Density with Brain Size" (1999). An overview of conventional contemporary models of long-term memory is found in Rutherford et al., "Long-Term Memory: Encoding to Retrieval" (2012).

[43] The term 'identification' has been used here in a loose sense; from the perspective of information security, what has just been described as 'identification' actually involves identification, authentication, and authorization.

[44] See Gasson (2012), p. 25.

[45] See Gasson (2012), p. 14.

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during the device's operation. Devices that are introduced into the body of their human host by nonsurgical means (such as nanorobots that are orally ingested) would not be 'implants' in this sense, even if they establish a permanent connection with particular neurons after their entry into their host's body; such technologies could be described more broadly as '**endosomatic**' devices or systems that are housed within their host's body but are not surgically implanted. Neuroprosthetic devices formed of biological components that are grown or cultivated *in situ* within their host's body would be another example of such endosomatic systems that are not, strictly speaking, implants.

Meanwhile, we can define a neurocybernetic '**prosthesis**' as a device that is integrated into the neural circuitry of its human host but which is not completely contained within the host's body; it instead forms part of the exterior surface or boundary of the body and extends the body outward into the surrounding environment. It is possible for a single device to be both a neuroprosthetic implant and a prosthesis: for example, an artificial eye that has been surgically implanted but which (at least, when the eyelid is open) forms part of the body's exterior surface and a portion of its physical interface with the external environment. It is also possible for an implant and prosthesis to work together closely as part of a larger system. For example, an individual who has lost an arm due to injury may now possess a permanent implant located in the shoulder area that is integrated with the sensory and motor nerves that previously innervated the arm. If that implant contains an external socket that allows different robotic arms to be attached to it and controlled by the device's host (or which perhaps even allows different kinds of robotic limbs and manipulators to be swapped in and out of the socket), then the socket itself would be considered an implant, and a robotic arm capable of connecting with the socket (and, through it, becoming indirectly integrated into the neural circuitry of the device's human host) would be considered a prosthesis.

Note that some other texts that focus specifically on brain-computer interfaces (BCIs) may use terms such as 'invasive,' 'partially invasive,' and 'noninvasive' to refer to a device's physical relationship to the *brain* of its human host rather than its relationship to the host's body as a whole. According to such definitions, a device could be wholly contained within the body of its human host but would be classified as 'noninvasive' if it were implanted in, say, the host's abdomen rather than the gray matter of his or her brain.[46] As defined in this text, a neuroprosthetic device must be integrated into the 'neural circuitry' of its human host, but this does not necessarily require a

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[46] See Gasson (2012), p. 14, and Panoulas et al., "Brain-Computer Interface (BCI): Types, Processing Perspectives and Applications" (2010).

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connection to interneurons contained within the *brain*; a neuroprosthetic device could be located elsewhere in the body and possess a physical interface with afferent or efferent neurons in that location. In the context of this book, 'invasive' is best used to refer to neuroprosthetic devices that are endosomatic or fully contained within the human body of their host; 'noninvasive' neuroprosthetic devices would be those that have no physical components contained within the body of their human host (such devices might include wearable neuroprostheses that rest on the external surface of the body and which communicate with neurons via signals transmitted through the skin, or even devices that can communicate with neurons at a greater distance through the generation and detection of electromagnetic fields or radiation); and 'semi-invasive' neuroprosthetic devices would be those that have components that are external to (and perhaps not even physically connected to) their host's body but which simultaneously possess some components that must be introduced into the body of their human host (such as electronic components that must be inserted into the ear canal or through a permanent port installed in the body via a surgically created stoma, or biochemical agents that must be introduced into the host's bloodstream).

D. Neuroprosthetic devices categorized by agency: active vs. passive

With regard to their interaction with the biological structures and processes of their human host, some neuroprosthetic devices may be considered '**active**,' insofar as they possess an internal computer or other mechanism (e.g., a transmitter that allows the device to receive instructions from an external system) that governs the device's behavior and allows the device to proactively undertake actions and to determine how it will respond to stimuli received from its human host or the external environment. A '**passive**' neuroprosthetic device, on the other hand, is essentially an inert tool that lacks its own centralized internal control mechanism and whose behavior is controlled by the biological processes of and input supplied by the device's human host.[47]

An artificial eye that uses its built-in video camera to register light from the external environment, utilizes its internal computer to process those incoming signals and convert them into a pattern of stimuli, and then stimulates retinal ganglion cells according to that pattern would be an active neuroprosthetic device; its internal computer governs its behavior, and if an adversary were able to access and compromise the computer, he or she could

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[47] For one approach to classifying information and communications technology (ICT) implants as 'active' or 'passive' with regard for their functionality, see Roosendaal, "Implants and Human Rights, in Particular Bodily Integrity" (2012).

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potentially use the device to supply its host with manipulated or even entirely fabricated visual data.[48]

On the other hand, an example of a passive implant would be an array of synthetic biomimetic physical neurons that is implanted into its host's brain to replace a group of natural biological neurons that had been destroyed through illness or injury. Although each individual synthetic neuron may possess a limited form of agency and control over its own actions – insofar as it possesses mechanisms that determine how it will react to particular stimuli – the device as a whole possesses no centralized control mechanism and is, in essence, an empty scaffolding that cannot fill itself with information or decide to take action. The natural biological neurons that are connected to the implant may eventually begin to 'use' it by supplying stimuli to it and incorporating it into their network of activity and information storage, but such action cannot be forced or compelled by the implant itself.

Attacks against active vs. passive neuroprostheses

Note that if a neuroprosthetic device is controlled by an internal computer that possesses its own memory, processor, and input/output mechanisms and which runs its own operating system (and potentially additional specialized software), the device is almost certainly an 'active' one, even if the intended purpose of the device is simply to detect the wishes and volitions of its human host and then to execute them. Although such a device may typically operate in a way that creates the *appearance* that it is strictly passive, an adversary who gained access to the device's computer and compromised its hardware or software could use the device as (or turn the device into) an active agent that behaves in ways that were not at all requested or desired by the device's human host. On the other hand, a purely passive neuroprosthetic device could not be directly hijacked by an adversary and utilized to perform certain actions or behaviors, because the device itself has no internal control mechanism that can be commandeered; the only way that an adversary could indirectly dictate the actions of a passive neuroprosthetic device (without radically reengineering the device itself) would be to control the biological structures or processes of the device's human host that interact with the device, causing them to externally stimulate the device in ways that would produce a particular response.

E. Implantable computers vs. neuroprosthetic devices

Not all implantable computers are neuroprosthetic devices: it is possible to have a miniaturized computer (e.g., as part of an active RFID transponder) that is implanted within a human being's body but which has no interface or

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[48] Regarding such possibilities of neuroprostheses being used to provide false data or information to their hosts or users, see McGee (2008), p. 221.

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interaction with the person's neural circuitry. Conversely, not every neuroprosthetic device is (or contains) an 'implantable' computer: for example, the external portion of a prosthetic arm may contain a highly sophisticated computer that is integrated into the neural circuitry of its human host through a stable physical connection and interaction with nerves in the person's shoulder, however the computer would be considered part of a 'prosthesis' rather than an 'implant.'

II. Expected developments in neuroprosthetics: toward posthuman enhancement

The kinds of neuroprosthetic devices that are currently in widespread use have typically been designed to serve a restorative or therapeutic medical purpose – for example, to treat a particular illness or restore some sensory, motor, or cognitive ability that their user has lost as a result of illness or injury. It is expected, though, that future generations of neuroprostheses will increasingly be designed not to restore some ordinary human capacity that is absent but to enhance their user's physical or intellectual capacities by providing abilities that exceed or differ from what is naturally possible for human beings.[49] The potential use of such technologies for physical and cognitive enhancement is expected to expand the market for neuroprostheses and implantable computers to reach new audiences well beyond the limited segment of the population that currently relies on them to treat medical conditions.[50]

Researchers expect that future versions of sensory neuroprostheses such as retinal implants may give human beings the capacity to experience their environments in dramatically new ways, for example through the use of telescopic or night vision[51] or by using a form of augmented reality that overlays actual sense data provided by the environment with supplemental information received or generated by a neuroprosthetic device's computer.[52] Some researchers envision the development of devices that resemble more sophisticated forms of retinal and cochlear implants that can record all of a person's audiovisual experiences for later playback on demand, effectively granting

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[49] See Gasson (2008); Gasson et al. (2012); McGee (2008); and Merkel et al. (2007).

[50] See McGee (2008) and Gasson et al. (2012).

[51] See Gasson et al. (2012) and Merkel et al. (2007).

[52] See Koops & Leenes, "Cheating with Implants: Implications of the Hidden Information Advantage of Bionic Ears and Eyes" (2012).

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the person perfect audiovisual memory[53] and potentially allowing the individual to share his or her sensory experiences with others (e.g., through automatic upload to a streaming website).

Building on successful experiments with implanting artificial memories in mice, other researchers have envisioned the possibility of a person being able to regularly download new content onto a memory chip implanted in his or her brain, thereby instantaneously gaining access to new knowledge or skills.[54] Even more futuristic scenarios envisioned by scholars include the development of a 'knowledge pill' that can be ingested and whose contents – perhaps a swarm of web-enabled nanorobots[55] – travel to the brain, where they modify or stimulate neurons to create engrams containing particular memories.[56] Another potentially revolutionary technological advancement is the ongoing development of brain-machine-brain interfaces[57] that may eventually allow direct and instantaneous communication between two human brains physically located thousands of miles apart.

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[53] See Merkel et al. (2007) and Robinett, "The consequences of fully understanding the brain" (2002).

[54] See McGee (2008).

[55] See Pearce, "The Biointelligence Explosion" (2012).

[56] See Spohrer, "NBICS (Nano-Bio-Info-Cogno-Socio) Convergence to Improve Human Performance: Opportunities and Challenges" (2002).

[57] See Rao et al., "A direct brain-to-brain interface in humans" (2014). Existing experimental technologies of this sort are sometimes described as 'brain-brain interfaces' (BBIs), although we would argue that such terminology is somewhat misleading; it would be more appropriate to describe the system as a 'brain-machine-brain interface' (BMBI) or 'brain-computer-brain-interface' (BCBI). If one were allowed to describe as a 'brain-brain interface' a system that actually interposes between the two brains some complex technological device that enables and mediates their communication, then traditional technologies such as telephones and even books could similarly be described as 'brain-brain interfaces' with just as much legitimacy. It can be argued that a true 'brain-brain interface' would instead be one in which the communication between the two brains does not rely on any 'external' device or system; rather, the means of communication between the two brains would be contained within and fully integrated into one or both of the brains themselves. An electronic transmitter that is permanently implanted within a host's brain and which harvests energy from the brain itself and allows the brain to communicate with other brains possessing similar devices could conceivably be described as a 'brain-brain interface.' A clearer example would be that of a prosthesis composed of biological material that is either implanted into or grown or assembled within a brain, and which through its unique organic design is capable of generating and detecting radio frequency transmissions, light, electromagnetic fields, ultrasonic waves, or other phenomena that are detectable at a distance. If two brains possessing such prostheses were able to communicate with one another by means of the devices, this could well be understood as an example of a 'brain-brain interface,' even if the devices in fact were reliant on a medium (such as that of the atmosphere) for transmission of their signals. In its functioning, such a system would approach traditional definitions of 'telepathy.'

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A. Early adopters of neuroprosthetic devices for posthuman enhancement

One group of potential 'early adopters' of neuroprosthetic devices designed for human enhancement includes military forces, intelligence agencies, police forces, and other government agencies that may use such technologies to enhance the capacities of their personnel to engage in conventional combat operations, cyberwarfare, and the gathering and analysis of intelligence.[58] Another potential group of early adopters of such technologies includes hardcore computer gamers (including professional competitive gamers) who wish to experience more sophisticated and immersive forms of sensorimotor interaction with game-worlds and cybernetic interaction with their fellow gamers than can be provided by external virtual reality systems.

B. The meaning of 'advanced' neuroprosthetics

This text addresses the necessity of and practices for ensuring information security for advanced neuroprosthetic devices. By 'advanced,' we mean that this book considers all types of neuroprosthetic devices whose future development is anticipated and not simply those kinds that already are in widespread use among human beings (like cochlear implants), are undergoing testing for therapeutic use in human beings (like retinal prostheses with limited visual resolution), or which are currently being tested in animals but could potentially be adapted someday for use in human beings (like some kinds of mnemoprostheses designed to create or alter particular memories).

Many of the IMDs that are currently in use around the world – especially those that were implanted years or even decades ago – present both an advantage and a unique challenge from the perspective of information security, insofar as their internal computers are severely constrained in their capacities and functionality; this may prevent one from applying conventional InfoSec mechanisms and software that are commonly employed with more powerful computers (e.g., those found in desktop computers or smartphones) while simultaneously shielding the devices from attacks to which only more powerful conventional computers and operating systems may be vulnerable. Looking ahead to the future, though, we can anticipate the need to provide information security to implanted neuroprosthetic devices that differ radically from today's best desktop computers not in being much less powerful than they are but in being much *more* so – or in utilizing exotic hardware and software platforms (such as biomolecular computing) that have little in common with today's computers designed for general office or home use.

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[58] On potential military use of neuroprosthetic devices, see Schermer, "The Mind and the Machine. On the Conceptual and Moral Implications of Brain-Machine Interaction" (2009), and Brunner & Schalk, "Brain-Computer Interaction" (2009).

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While this text considers all such devices that are currently in widespread use or are undergoing testing, the scope of the book is broader: it also addresses the information security needs of those more advanced kinds of neuroprosthetic devices (such as artificial eyes possessing human-like visual resolution) that scientists, engineers, and entrepreneurs have declared their intention to create and are actively working to bring to market, as well as more sophisticated neuroprosthetic devices whose eventual development is expected by researchers and professional futurists and whose legal, ethical, political, economic, cultural and technological implications are already being debated by the proponents and critics of such technologies.

Among such potential future neuroprosthetic technologies are ones that may allow human beings to acquire new sensory capacities, adopt radically nonhuman bodies, inhabit virtual worlds in which different laws of physics and biology hold sway, and directly link their minds with one another or with artificial intelligences to create new kinds of communal thought and agency.[59] Although today there is not yet a widespread practical necessity to *implement* InfoSec mechanisms and procedures for such systems, it is important to begin developing the theoretical, conceptual, and organizational frameworks that will be needed to promote the information security of systems utilizing such technologies – especially insofar as the formulation of sound information security frameworks can aid those individuals and organizations that are actively pursuing the development of such technologies, to help ensure that they are designed and eventually deployed in ways that will advance rather than undermine essential aims such as human authenticity, agency, and full human development.[60]

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[59] See Merkel et al. (2007); Gladden, "Cybershells, Shapeshifting, and Neuroprosthetics" (2015); and Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016).

[60] See Gladden, "Neural Implants as Gateways to Digital-Physical Ecosystems and Posthuman Socioeconomic Interaction" (2016).

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Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-09-2 (print edition) and 978-1-944373-10-8 (ebook).

References

Abrams, Jerold J. “Pragmatism, Artificial Intelligence, and Posthuman Bioethics: Shusterman, Rorty, Foucault.” *Human Studies* 27, no. 3 (2004): 241-58.

Al-Hudhud, Ghada. “On Swarming Medical Nanorobots.” *International Journal of Bio-Science & Bio-Technology* 4, no. 1 (2012): 75-90.

Ameen, Moshaddique Al, Jingwei Liu, and Kyungsup Kwak. “Security and Privacy Issues in Wireless Sensor Networks for Healthcare Applications.” *Journal of Medical Systems* 36, no. 1 (2010): 93-101.

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.

Ansari, Sohail, K. Chaudhri, and K. Al Moutaery. “Vagus Nerve Stimulation: Indications and Limitations.” In *Operative Neuromodulation*, edited by Damianos E. Sakas and Brian A. Simpson, pp. 281-86. Acta Neurochirurgica Supplements 97/2. Springer Vienna, 2007.

Armando, Alessandro, Gabriele Costa, Alessio Merlo, and Luca Verderame. “Formal Modeling and Automatic Enforcement of Bring Your Own Device Policies.” *International Journal of Information Security* (2014): 1-18.

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, pp. 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.

Badmington, Neil. “Cultural Studies and the Posthumanities,” edited by Gary Hall and Claire Birchall. *New Cultural Studies: Adventures in Theory*, pp. 260-72. Edinburgh: Edinburgh University Press, 2006.

Baudrillard, Jean. *Simulacra and Simulation*. Ann Arbor: University of Michigan Press, 1994.

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

Benedict, M., and H. Schlieter. “Governance Guidelines for Digital Healthcare Ecosystems,” in *EHealth2015 – Health Informatics Meets EHealth: Innovative Health Perspectives: Personalized Health,* pp. 233-40. 2015.

“An Introduction to Advanced Neuroprosthetics,” Chapter One in
Gladden, Matthew E., The Handbook of Information Security for Advanced Neuroprosthetics (Second Edition), pp. 25-41.
Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-09-2 (print edition) and 978-1-944373-10-8 (ebook).

Bergamasco, S., M. Bon, and P. Inchingolo. “Medical data protection with a new generation of hardware authentication tokens.” In *IFMBE Proceedings MEDICON 2001*, edited by R. Magjarevic, S. Tonkovic, V. Bilas, and I. Lackovic, pp. 82-85. IFMBE, 2001.

Birbaumer, Niels, and Klaus Haagen. “Restoration of Movement and Thought from Neuroelectric and Metabolic Brain Activity: Brain-Computer Interfaces (BCIs).” In *Intelligent Computing Everywhere*, edited by Alfons J. Schuster, pp. 129-52. Springer London, 2007.

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.

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

Borton, D. A., Y.-K. Song, W. R. Patterson, C. W. Bull, S. Park, F. Laiwalla, J. P. Donoghue, and A. V. Nurmikko. “Implantable Wireless Cortical Recording Device for Primates.” In *World Congress on Medical Physics and Biomedical Engineering, September 7-12, 2009, Munich, Germany*, edited by Olaf Dössel and Wolfgang C. Schlegel, pp. 384-87. IFMBE Proceedings 25/9. Springer Berlin Heidelberg, 2009.

Bostrom, Nick. “Why I Want to Be a Posthuman When I Grow Up.” In *Medical Enhancement and Posthumanity*, edited by Bert Gordijn and Ruth Chadwick, pp. 107-36. The International Library of Ethics, Law and Technology 2. Springer Netherlands, 2008.

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

Bowman, Diana M., Mark N. Gasson, and Eleni Kosta. “The Societal Reality of That Which Was Once Science Fiction.” In *Human ICT Implants: Technical, Legal and Ethical Considerations*, edited by Mark N. Gasson, Eleni Kosta, and Diana M. Bowman, pp. 175-79. Information Technology and Law Series 23. T. M. C. Asser Press, 2012.

Brey, Philip. “Ethical Aspects of Information Security and Privacy.” In *Security, Privacy, and Trust in Modern Data Management*, edited by Milan Petković and Willem Jonker, pp. 21-36. Data-Centric Systems and Applications. Springer Berlin Heidelberg, 2007.

“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, pp. 719-23. Lecture Notes in Computer Science 5638. Springer Berlin Heidelberg, 2009.

Buller, Tom. “Neurotechnology, Invasiveness and the Extended Mind.” *Neuroethics* 6, no. 3 (2011): 593-605.

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

Campbell, Courtney S., James F. Keenan, David R. Loy, Kathleen Matthews, Terry Winograd, and Laurie Zoloth. “The Machine in the Body: Ethical and Religious Issues in the Bodily Incorporation of Mechanical Devices.” In *Altering Nature*, edited by B. Andrew Lustig, Baruch A. Brody, and Gerald P. McKenny, pp. 199-257. Philosophy and Medicine 98. Springer Netherlands, 2008.

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, pp. 437-42. Acta Neurochirurgica Supplements 97/2. Springer Vienna, 2007.

“An Introduction to Advanced Neuroprosthetics,” Chapter One in
Gladden, Matthew E., The Handbook of Information Security for Advanced Neuroprosthetics (Second Edition), pp. 25-41.
Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-09-2 (print edition) and 978-1-944373-10-8 (ebook).

Chadwick, Ruth. “Therapy, Enhancement and Improvement.” In *Medical Enhancement and Posthumanity*, edited by Bert Gordijn and Ruth Chadwick, pp. 25-37. The International Library of Ethics, Law and Technology 2. Springer Netherlands, 2008.

Chaudhry, Peggy E., Sohail S. Chaudhry, Ronald Reese, and Darryl S. Jones. “Enterprise Information Systems Security: A Conceptual Framework.” In *Re-Conceptualizing Enterprise Information Systems*, edited by Charles Møller and Sohail Chaudhry, pp. 118-28. Lecture Notes in Business Information Processing 105. Springer Berlin Heidelberg, 2012.

Cho, Kwantae, and Dong Hoon Lee. “Biometric Based Secure Communications without Pre-Deployed Key for Biosensor Implanted in Body Sensor Networks.” In *Information Security Applications*, edited by Souhwan Jung and Moti Yung, pp. 203-18. Lecture Notes in Computer Science 7115. Springer Berlin Heidelberg, 2012.

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

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.

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

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

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.

Coles-Kemp, Lizzie, and Marianthi Theoharidou. “Insider Threat and Information Security Management.” In *Insider Threats in Cyber Security*, edited by Christian W. Probst, Jeffrey Hunker, Dieter Gollmann, and Matt Bishop, pp. 45-71. Advances in Information Security 49. Springer US, 2010.

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.

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.

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

Dardick, Glenn. “Cyber Forensics Assurance.” In *Proceedings of the 8th Australian Digital Forensics Conference*, pp. 57-64. Research Online, 2010.

Datteri, E. “Predicting the Long-Term Effects of Human-Robot Interaction: A Reflection on Responsibility in Medical Robotics.” *Science and Engineering Ethics* 19, no. 1 (2013): 139-60.

Delac, Kresimir, and Mislav Grgic. “A Survey of Biometric Recognition Methods.” In *Proceedings of the 46th International Symposium on Electronics in Marine, ELMAR 2004*, pp. 184-93. IEEE, 2004.

“An Introduction to Advanced Neuroprosthetics,” Chapter One in
Gladden, Matthew E., The Handbook of Information Security for Advanced Neuroprosthetics (Second Edition), pp. 25-41.
Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-09-2 (print edition) and 978-1-944373-10-8 (ebook).

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*, pp. 917-26. ACM, 2010.

Denning, Tamara, Kevin Fu, and Tadayoshi Kohno. “Absence Makes the Heart Grow Fonder: New Directions for Implantable Medical Device Security.” 3rd USENIX Workshop on Hot Topics in Security (HotSec 2008). San Jose, CA, July 29, 2008.

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

Donchin, Emanuel, and Yael Arbel. “P300 Based Brain Computer Interfaces: A Progress Report.” In *Foundations of Augmented Cognition. Neuroergonomics and Operational Neuroscience*, edited by Dylan D. Schmorrow, Ivy V. Estabrooke, and Marc Grootjen, pp. 724-31. Lecture Notes in Computer Science 5638. Springer Berlin Heidelberg, 2009.

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.

Drongelen, Wim van, 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.

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

Durand, Dominique M., Warren M. Grill, and Robert Kirsch. “Electrical Stimulation of the Neuromuscular System.” In *Neural Engineering*, edited by Bin He, pp. 157-91. Bioelectric Engineering. Springer US, 2005.

Dvorsky, George. “What may be the world’s first cybernetic hate crime unfolds in French McDonald’s.” io9, July 17, 2012. http://io9.com/5926587/what-may-be-the-worlds-first-cybernetic-hate-crime-unfolds-in-french-mcdonalds. Accessed July 22, 2015.

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, pp. 1003-17. Springer Berlin Heidelberg, 2011.

Erler, Alexandre. “Does Memory Modification Threaten Our Authenticity?” *Neuroethics* 4, no. 3 (2011): 235-49.

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.

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.

Fernandes, Diogo A. B., Liliana F. B. Soares, João V. Gomes, Mário M. Freire, and Pedro R. M. Inácio. “Security Issues in Cloud Environments: A Survey.” *International Journal of Information Security* 13, no. 2 (2013): 113-70.

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.

FIPS PUB 199: Standards for Security Categorization of Federal Information and Information Systems. Gaithersburg, MD: National Institute of Standards and Technology, 2004.

“An Introduction to Advanced Neuroprosthetics,” Chapter One in
Gladden, Matthew E., The Handbook of Information Security for Advanced Neuroprosthetics (Second Edition), pp. 25-41.
Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-09-2 (print edition) and 978-1-944373-10-8 (ebook).

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.

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, pp. 357-62. Acta Neurochirurgica Supplements 97/2. Springer Vienna, 2007.

Freudenthal, Eric, Ryan Spring, and Leonardo Estevez. "Practical techniques for limiting disclosure of RF-equipped medical devices." In *Engineering in Medicine and Biology Workshop, 2007 IEEE Dallas*, pp. 82-85. IEEE, 2007.

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

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

Gärtner, Armin. "Communicating Medical Systems and Networks." In *Springer Handbook of Medical Technology*, edited by Rüdiger Kramme, Klaus-Peter Hoffmann, and Robert S. Pozos, pp. 1085-93. Springer Berlin Heidelberg, 2011.

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.

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.

Gerhardt, Greg A., and Patrick A. Tresco. "Sensor Technology." In *Brain-Computer Interfaces*, pp. 7-29. Springer Netherlands, 2008.

Gladden, Matthew E. "Cryptocurrency with a Conscience: Using Artificial Intelligence to Develop Money that Advances Human Ethical Values." *Annales: Ethics in Economic Life* vol. 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. "A Fractal Measure for Comparing the Work Effort of Human and Artificial Agents Performing Management Functions." In *Position Papers of the 2014 Federated Conference on Computer Science and Information Systems*, edited by Maria Ganzha, Leszek Maciaszek, Marcin Paprzycki, pp. 219-26. Annals of Computer Science and Information Systems 3. Polskie Towarzystwo Informatyczne, 2014.

"An Introduction to Advanced Neuroprosthetics," Chapter One in
Gladden, Matthew E., The Handbook of Information Security for Advanced Neuroprosthetics (Second Edition), pp. 25-41.
Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-09-2 (print edition) and 978-1-944373-10-8 (ebook).

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

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. “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. *Neuroprosthetic Supersystems Architecture.* Indianapolis: Synthypnion Academic, 2017.

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

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

Graham, Elaine. *Representations of the Post/Human: Monsters, Aliens and Others in Popular Culture*. Manchester: Manchester University Press, 2002.

Greenberg, Andy. “Cyborg Discrimination? Scientist Says McDonald's Staff Tried To Pull Off His Google-Glass-Like Eyepiece, Then Threw Him Out.” Forbes, July 17, 2012. http://www.forbes.com/sites/andygreenberg/2012/07/17/cyborg-discrimination-scientist-says-mcdonalds-staff-tried-to-pull-off-his-google-glass-like-eyepiece-then-threw-him-out/. Accessed July 22, 2015.

Grodzinsky, F.S., K.W. Miller, and M.J. Wolf. “Developing Artificial Agents Worthy of Trust: ‘Would You Buy a Used Car from This Artificial Agent?’” *Ethics and Information Technology* 13, no. 1 (2011): 17-27.

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.

Guidance for Industry - Cybersecurity for Networked Medical Devices Containing Off-the-Shelf (OTS) Software. Silver Spring, MD: US Food and Drug Administration, 2005.

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

Gunther, N. J. “Time—the zeroth performance metric.” In *Analyzing Computer System Performance with Perl::PDQ*, 3-46. Berlin: Springer, 2005.

Halperin, Daniel, Tadayoshi Kohno, Thomas S. Heydt-Benjamin, Kevin Fu, and William H. Maisel. “Security and privacy for implantable medical devices.” *Pervasive Computing, IEEE* 7, no. 1 (2008): 30-39.

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.

Hansen, Jeremy A., and Nicole M. Hansen. “A Taxonomy of Vulnerabilities in Implantable Medical Devices.” In *Proceedings of the Second Annual Workshop on Security and Privacy in Medical and Home-Care Systems*, pp. 13-20. ACM, 2010.

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

Haraway, Donna. “A Manifesto for Cyborgs: Science, Technology, and Socialist Feminism in the 1980s.” *Socialist Review* 15, no. 2 (1985): 65-107.

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

Harrison, Ian. “IEC80001 and Future Ramifications for Health Systems Not Currently Classed as Medical Devices.” In *Making Systems Safer*, edited by Chris Dale and Tom Anderson, pp. 149-71. Springer London, 2010.

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.

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

Heersmink, Richard. “Embodied Tools, Cognitive Tools and Brain-Computer Interfaces.” *Neuroethics* 6, no. 1 (2011): 207-19.

Hei, Xiali, and Xiaojiang Du. “Biometric-based two-level secure access control for implantable medical devices during emergencies.” In *INFOCOM, 2011 Proceedings IEEE*, pp. 346-350. IEEE, 2011.

Hellström, T. “On the Moral Responsibility of Military Robots.” *Ethics and Information Technology* 15, no. 2 (2013): 99-107.

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

Hern, Alex. “Hacker fakes German minister's fingerprints using photos of her hands.” The Guardian, December 30, 2014. http://www.theguardian.com/technology/2014/dec/30/hacker-fakes-german-ministers-fingerprints-using-photos-of-her-hands. Accessed July 24, 2015.

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.

Hildebrandt, Mireille, and Bernhard Anrig. “Ethical Implications of ICT Implants.” In *Human ICT Implants: Technical, Legal and Ethical Considerations*, edited by Mark N. Gasson, Eleni Kosta, and Diana M. Bowman, pp. 135-58. Information Technology and Law Series 23. T. M. C. Asser Press, 2012.

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.

Humphreys, L., J. M. Ferrández, and E. Fernández. “Long Term Modulation and Control of Neuronal Firing in Excitable Tissue Using Optogenetics.” In *Foundations on Natural and Artificial Computation*, edited by José Manuel Ferrández, José Ramón Álvarez Sánchez, Félix de la Paz, and F. Javier Toledo, pp. 266-73. Lecture Notes in Computer Science 6686. Springer Berlin Heidelberg, 2011.

“An Introduction to Advanced Neuroprosthetics,” Chapter One in
Gladden, Matthew E., The Handbook of Information Security for Advanced Neuroprosthetics (Second Edition), pp. 25-41.
Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-09-2 (print edition) and 978-1-944373-10-8 (ebook).

IEC 80001: Application of risk management for IT-networks incorporating medical devices, Parts 1 through 2-7. ISO/TC 215. Geneva: IEC, 2010-15.

Illes, Judy. *Neuroethics: Defining the Issues in Theory, Practice, and Policy*. Oxford University Press, 2006.

ISO 27799:2008, Health informatics – Information security management in health using ISO/IEC 27002. ISO/TC 215. Geneva: ISO/IEC, 2008.

ISO/IEC 27001:2013, Information technology – Security techniques – Information security management systems – Requirements. ISO/IEC JTC 1/SC 27. Geneva: ISO/IEC, 2013.

ISO/IEC 27002:2013, Information technology – Security techniques – Code of practice for information security controls. ISO/IEC JTC 1/SC 27. Geneva: ISO/IEC, 2013.

ISO/TR 11633-1:2009, Health informatics – Information security management for remote maintenance of medical devices and medical information systems – Part 1: Requirements and risk analysis. ISO/TC 215. Geneva: ISO, 2009.

ISO/TR 11633-2:2009, Health informatics – Information security management for remote maintenance of medical devices and medical information systems – Part 2: Implementation of an information security management system (ISMS). ISO/TC 215. Geneva: ISO, 2009.

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.

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.

Kirkpatrick, K. “Legal Issues with Robots.” *Communications of the ACM* 56, no. 11 (2013): 17-19.

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.

Kłoda-Staniecko, Bartosz. “Ja, Cyborg. Trzy porządki, jeden byt. Podmiot jako fuzja biologii, kultury i technologii” (“I, Cyborg. Three Orders, One Being. Subject as a Fusion of Nature, Culture and Technology”). In *Człowiek w relacji do zwierząt, roślin i maszyn w kulturze: Tom I: Aspekt posthumanistyczny i transhumanistyczny*, edited by Justyny Tymienieckiej-Suchanek. Uniwersytet Śląski, 2015.

Koch, K. P. “Neural Prostheses and Biomedical Microsystems in Neurological Rehabilitation.” In *Operative Neuromodulation*, edited by Damianos E. Sakas, Brian A. Simpson, and Elliot S. Krames, pp. 427-34. Acta Neurochirurgica Supplements 97/1. Springer Vienna, 2007.

Koebler, Jason. “FCC Cracks Down on Cell Phone ‘Jammers’: The FCC says illegal devices that block cell phone signals could pose security risk.” *U.S. News & World Report*, October 17, 2012. http://www.usnews.com/news/articles/2012/10/17/fcc-cracks-down-on-cell-phone-jammers. Accessed July 22, 2015.

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.

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.

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 (2011): 483-97. doi:10.1007/s12152-011-9115-7.

Kuflik, A. “Computers in Control: Rational Transfer of Authority or Irresponsible Abdication of Autonomy?” *Ethics and Information Technology* 1, no. 3 (1999): 173-84.

Lebedev, M. “Brain-Machine Interfaces: An Overview.” *Translational Neuroscience* 5, no. 1 (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.

Lee, Giljae, Andréa Matsunaga, Salvador Dura-Bernal, Wenjie Zhang, William W. Lytton, Joseph T. Francis, and José AB Fortes. “Towards Real-Time Communication between in Vivo Neurophysiological Data Sources and Simulator-Based Brain Biomimetic Models.” *Journal of Computational Surgery* 3, no. 1 (2014): 1-23.

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.

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

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

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

Lucivero, Federica, and Guglielmo Tamburrini. “Ethical Monitoring of Brain-Machine Interfaces.” *AI & SOCIETY* 22, no. 3 (2007): 449-60.

Ma, Ting, Ying-Ying Gu, and Yuan-Ting Zhang. “Circuit Models for Neural Information Processing.” In *Neural Engineering*, edited by Bin He, pp. 333-65. Bioelectric Engineering. Springer US, 2005.

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.

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

“An Introduction to Advanced Neuroprosthetics,” Chapter One in
Gladden, Matthew E., The Handbook of Information Security for Advanced Neuroprosthetics (Second Edition), pp. 25-41.
Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-09-2 (print edition) and 978-1-944373-10-8 (ebook).

Maj, Krzysztof. “Rational Technotopia vs. Corporational Dystopia in ‘Deus Ex: Human Revolution’ Gameworld.” His Master's Voice: Utopias and Dystopias in Audiovisual Culture. Facta Ficta Research Centre / Jagiellonian University, Kraków, March 24, 2015.

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

Masani, Kei, and Milos R. Popovic. “Functional Electrical Stimulation in Rehabilitation and Neurorehabilitation.” In *Springer Handbook of Medical Technology*, edited by Rüdiger Kramme, Klaus-Peter Hoffmann, and Robert S. Pozos, pp. 877-96. Springer Berlin Heidelberg, 2011.

McCormick, Michael. “Data Theft: A Prototypical Insider Threat.” In *Insider Attack and Cyber Security*, edited by Salvatore J. Stolfo, Steven M. Bellovin, Angelos D. Keromytis, Shlomo Hershkop, Sean W. Smith, and Sara Sinclair, pp. 53-68. Advances in Information Security 39. Springer US, 2008.

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 (2013): 109-22.

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.

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.

Medical Enhancement and Posthumanity, edited by Bert Gordijn and Ruth Chadwick. The International Library of Ethics, Law and Technology 2. Springer Netherlands, 2008.

Meloy, Stuart. “Neurally Augmented Sexual Function.” In *Operative Neuromodulation*, edited by Damianos E. Sakas, Brian A. Simpson, and Elliot S. Krames, pp. 359-63. Acta Neurochirurgica Supplements 97/1. Springer Vienna, 2007.

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.

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.

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 (2009): 401-14.

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

Moxon, Karen A. “Neurorobotics.” In *Neural Engineering*, edited by Bin He, pp. 123-55. Bioelectric Engineering. Springer US, 2005.

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.

NIST Special Publication 800-33: Underlying Technical Models for Information Technology Security. Edited by Gary Stoneburner. Gaithersburg, Maryland: National Institute of Standards & Technology, 2001.

NIST Special Publication 800-37, Revision 1: Guide for Applying the Risk Management Framework to Federal Information Systems: A Security Life Cycle Approach. Joint Task Force Transformation Initiative. Gaithersburg, Maryland: National Institute of Standards & Technology, 2010.

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

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

NIST Special Publication 1800-1: Securing Electronic Health Records on Mobile Devices (Draft), Parts a, b, c, d, and e. Edited by G. O’Brien, N. Lesser, B. Pleasant, S. Wang, K. Zheng, C. Bowers, K. Kamke, and L. Kauffman. Gaithersburg, Maryland: National Institute of Standards & Technology, 2015.

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.

Overman, Stephenie. “Jamming Employee Phones Illegal.” Society for Human Resource Management, May 9, 2014. http://www.shrm.org/hrdisciplines/technology/articles/pages/cellphone-jamming.aspx. Accessed July 22, 2015.

Pająk, Robert. Email correspondence with the author, May 3, 2015.

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 “Our Excessively Simplistic Information Security Model and How to Fix It.” *ISSA Journal* (July 2010): 12-21.

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.

Passeraub, Ph A., and N. V. Thakor. “Interfacing Neural Tissue with Microsystems.” In *Neural Engineering*, edited by Bin He, 49-83. Bioelectric Engineering. Springer US, 2005.

“An Introduction to Advanced Neuroprosthetics,” Chapter One in
Gladden, Matthew E., The Handbook of Information Security for Advanced Neuroprosthetics (Second Edition), pp. 25-41.
Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-09-2 (print edition) and 978-1-944373-10-8 (ebook).

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

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.

Polikov, Vadim S., Patrick A. Tresco, and William M. Reichert. “Response of brain tissue to chronically implanted neural electrodes.” *Journal of Neuroscience Methods* 148, no. 1 (2005): 1-18.

Posthuman Bodies, edited by Judith Halberstam and Ira Livingstone. Bloomington, IN: Indiana University Press, 1995.

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.

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 (1999): 205-14.

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.

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

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.

Qureshi, Mohmad Kashif. “Liveness detection of biometric traits.” *International Journal of Information Technology and Knowledge Management* 4 (2011): 293-95.

Rahimi, Ali, Ben Recht, Jason Taylor, and Noah Vawter. “On the effectiveness of aluminium foil helmets: An empirical study.” MIT, February 17, 2005. http://web.archive.org/web/20100708230258/http://people.csail.mit.edu/rahimi/helmet/. Accessed July 26, 2015.

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

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).

Rasmussen, Kasper Bonne, Claude Castelluccia, Thomas S. Heydt-Benjamin, and Srdjan Capkun. “Proximity-based access control for implantable medical devices.” In *Proceedings of the 16th ACM conference on Computer and communications security*, pp. 410-19. ACM, 2009.

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.

Roosendaal, Arnold. “Carrying Implants and Carrying Risks; Human ICT Implants and Liability.” In *Human ICT Implants: Technical, Legal and Ethical Considerations*, edited by Mark

“An Introduction to Advanced Neuroprosthetics,” Chapter One in
Gladden, Matthew E., The Handbook of Information Security for Advanced Neuroprosthetics (Second Edition), pp. 25-41.
Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-09-2 (print edition) and 978-1-944373-10-8 (ebook).

N. Gasson, Eleni Kosta, and Diana M. Bowman, pp. 69-79. Information Technology and Law Series 23. T. M. C. Asser Press, 2012.

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.

Rossebeø, J. E. Y., M. S. Lund, K. E. Husa, and A. Refsdal, “A conceptual model for service availability.” In *Quality of Protection*, pp. 107-18. Advances in Information Security 23. Springer US, 2006.

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.

Rotter, Pawel, and Mark N. Gasson. “Implantable Medical Devices: Privacy and Security Concerns.” In *Human ICT Implants: Technical, Legal and Ethical Considerations*, edited by Mark N. Gasson, Eleni Kosta, and Diana M. Bowman, pp. 63-66. Information Technology and Law Series 23. T. M. C. Asser Press, 2012.

Rotter, Pawel, Barbara Daskala, Ramon Compañó, Bernhard Anrig, and Claude Fuhrer. “Potential Application Areas for RFID Implants.” In *Human ICT Implants: Technical, Legal and Ethical Considerations*, edited by Mark N. Gasson, Eleni Kosta, and Diana M. Bowman, pp. 29-39. Information Technology and Law Series 23. T. M. C. Asser Press, 2012.

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

Rubin, Charles T. “What Is the Good of Transhumanism?” In *Medical Enhancement and Posthumanity*, edited by Bert Gordijn and Ruth Chadwick, pp. 137-56. The International Library of Ethics, Law and Technology 2. Springer Netherlands, 2008.

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.

Sakas, Damianos E., I. G. Panourias, and B. A. Simpson. “An Introduction to Neural Networks Surgery, a Field of Neuromodulation Which Is Based on Advances in Neural Networks Science and Digitised Brain Imaging.” In *Operative Neuromodulation*, edited by Damianos E. Sakas and Brian A. Simpson, pp. 3-13. Acta Neurochirurgica Supplements 97/2. Springer Vienna, 2007.

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

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.

Schechter, Stuart. “Security that is Meant to be Skin Deep: Using Ultraviolet Micropigmentation to Store Emergency-Access Keys for Implantable Medical Devices.” Microsoft Research, August 10, 2010. http://research.microsoft.com:8082/apps/pubs/default.aspx?id=135291. Accessed July 26, 2015.

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

“An Introduction to Advanced Neuroprosthetics,” Chapter One in
Gladden, Matthew E., The Handbook of Information Security for Advanced Neuroprosthetics (Second Edition), pp. 25-41.
Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-09-2 (print edition) and 978-1-944373-10-8 (ebook).

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

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.

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

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, Virginia: 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.

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.

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.

Tadeusiewicz, Ryszard, Pawel Rotter, and Mark N. Gasson. "Restoring Function: Application Exemplars of Medical ICT Implants." In *Human ICT Implants: Technical, Legal and Ethical Considerations*, edited by Mark N. Gasson, Eleni Kosta, and Diana M. Bowman, pp. 41-51. Information Technology and Law Series 23. T. M. C. Asser Press, 2012.

Taira, Takaomi, and T. Hori. "Diaphragm Pacing with a Spinal Cord Stimulator: Current State and Future Directions." In *Operative Neuromodulation*, edited by Damianos E. Sakas, Brian A. Simpson, and Elliot S. Krames, pp. 289-92. Acta Neurochirurgica Supplements 97/1. Springer Vienna, 2007.

Tamburrini, Guglielmo. "Brain to Computer Communication: Ethical Perspectives on Interaction Models." *Neuroethics* 2, no. 3 (2009): 137-49.

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

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.

Thonnard, Olivier, Leyla Bilge, Gavin O'Gorman, Seán Kiernan, and Martin Lee. "Industrial Espionage and Targeted Attacks: Understanding the Characteristics of an Escalating Threat." In *Research in Attacks, Intrusions, and Defenses*, edited by Davide Balzarotti, Salvatore J. Stolfo, and Marco Cova, pp. 64-85. Lecture Notes in Computer Science 7462. Springer Berlin Heidelberg, 2012.

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.

"An Introduction to Advanced Neuroprosthetics," Chapter One in
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Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-09-2 (print edition) and 978-1-944373-10-8 (ebook).

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.

Ullah, Sana, Henry Higgin, M. Arif Siddiqui, and Kyung Sup Kwak. “A Study of Implanted and Wearable Body Sensor Networks.” In *Agent and Multi-Agent Systems: Technologies and Applications*, edited by Ngoc Thanh Nguyen, Geun Sik Jo, Robert J. Howlett, and Lakhmi C. Jain, pp. 464-73. Lecture Notes in Computer Science 4953. Springer Berlin Heidelberg, 2008.

U.S. Code, Title 44 (Public Printing and Documents), Subchapter III (Information Security), Section 3542 (Definitions), cited in *NIST Special Publication 800-37, Revision 1*.

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.

Vildjiounaite, Elena, Satu-Marja Mäkelä, Mikko Lindholm, Reima Riihimäki, Vesa Kyllönen, Jani Mäntyjärvi, and Heikki Ailisto. “Unobtrusive Multimodal Biometrics for Ensuring Privacy and Information Security with Personal Devices.” In *Pervasive Computing*, edited by Kenneth P. Fishkin, Bernt Schiele, Paddy Nixon, and Aaron Quigley, pp. 187-201. Lecture Notes in Computer Science 3968. Springer Berlin Heidelberg, 2006.

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.

Wager, K.A., F. Wickham Lee, and J.P. Glaser. *Health Care Information Systems: A Practical Approach for Health Care Management.* John Wiley & Sons, 2013.

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.

Weber, R. H., and R. Weber. “General Approaches for a Legal Framework.” In *Internet of Things*, pp. 23-40. Springer Berlin/Heidelberg, 2010.

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

Weinberger, Sharon. “Mind Games.” *Washington Post*, January 14, 2007. http://www.washingtonpost.com/wp-dyn/content/article/2007/01/10/AR2007011001399.html. Accessed July 26, 2015.

“Welcome.” Medical Device Privacy Consortium. http://deviceprivacy.org. Accessed May 6, 2016.

Werkhoven, Peter. “Experience Machines: Capturing and Retrieving Personal Content.” In *E-Content*, edited by Peter A. Bruck, Zeger Karssen, Andrea Buchholz, and Ansgar Zerfass, pp. 183-202. Springer Berlin Heidelberg, 2005.

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

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.]

“An Introduction to Advanced Neuroprosthetics,” Chapter One in
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Indianapolis: Synthypnion Academic, 2017. ISBN 978-1-944373-09-2 (print edition) and 978-1-944373-10-8 (ebook).

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.

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.

Zamanian, Ali, and Cy Hardiman. “Electromagnetic radiation and human health: A review of sources and effects.” *High Frequency Electronics* 4, no. 3 (2005): 16-26.

Zaród, Marcin. “Constructing Hackers. Professional Biographies of Polish Hackers.” Digital Ecosystems. Digital Economy Lab, University of Warsaw, Warsaw, June 29, 2015.

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 (2009): 78-87.

Zheng, Guanglou, Gengfa Fang, Mehmet Orgun, and Rajan Shankaran. “A Non-key based security scheme supporting emergency treatment of wireless implants.” In *2014 IEEE International Conference on Communications (ICC)*, pp. 647-52. IEEE, 2014.

Zheng, Guanglou, Gengfa Fang, Mehmet Orgun, Rajan Shankaran, and Eryk Dutkiewicz. “Securing wireless medical implants using an ECG-based secret data sharing scheme.” In *2014 14th International Symposium on Communications and Information Technologies (ISCIT)*, pp. 373-77. IEEE, 2014.

Zheng, Guanglou, Gengfa Fang, Rajan Shankaran, Mehmet Orgun, and Eryk Dutkiewicz. “An ECG-based secret data sharing scheme supporting emergency treatment of Implantable Medical Devices.” In *2014 International Symposium on Wireless Personal Multimedia Communications (WPMC)*, pp. 624-28. IEEE, 2014.

“An Introduction to Advanced Neuroprosthetics,” Chapter One in
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