Are BMI Prosthetics Uncontrollable Frankensteinian Monsters?

Sara Weinberger[1], & Dov Greenbaum[1,2] **

1. The Zvi Meitar Institute for Legal Implications of Emerging Technologies, Radzyner Law School, Interdisciplinary Center, Herzliya

2. Department of Molecular Biophysics and Biochemistry, Yale University
** Corresponding author *dov.greenbaum@yale.edu; **dov.greenbaum@idc.ac.il***

Biography

Dov Greenbaum is the Director of the Zvi Meitar Institute for Legal Implications of Emerging Technologies Concurrently, he is also an Assistant Professor in the Department of Molecular Biophysics and Biochemistry at Yale University School of Medicine (adj).

Dov has degrees and post-doctoral fellowships from Yeshiva University, Yale University, University of California, Berkeley, ETH Zurich and Stanford University.

In addition to his academic affiliation and training, he is also an intellectual property attorney (California & USPTO), with particular experience in the fields of biopharmaceutical litigation, and hitech patent drafting and prosecution, including drafting in the fields of robotics, software, computer hardware, and defense.

Abstract
The growing use of brain machine interfaces (BMI) raise a number of legal and ethical concerns, in particular, when the BMI is controlling a prosthetic or other robotic device. For example, mediating a BMI via artificially intelligent (AI) software —particularly predictive AI software that may even take over control of the device in the event of too much noise— can confound issues of cause and effect. Significantly, the determination of cause is necessary for ascertaining and assigning criminal guilt. Further, recent research has shown that BMIs interfacing particularly via the brain's posterior parietal cortex (PPC) can result in smoother motions by the prosthetic, in part given the PPC's role in broadly planning limb movements. However, in tapping directly into this area of the brain, a prosthetic arguably will move as a result of preconscious thought rather than conscious thought, an important consideration when applied to criminal law that sees automatism as a potential defense. This distinction between conscious and preconscious control over a prosthetic becomes even more relevant as such an interface may also circumvent important command and control elements downstream of the BMI's collected neural impulses, those command and control elements being particularly relevant for our (at least colloquial) conception of free will.

KEYWORDS
Artificial Intelligence, Criminal Law, Brain Machine Interface, Mens Rea, Free Will, Prosthetics, posterior parietal cortex (PPC), Readiness Potential

1. Introduction

Nearly two centuries ago, during the dreary and bleak Mount Tambora volcanic winter of 1816, Mary Shelly began writing what would later become her magnum opus, Frankenstein. No other work of fiction can claim to have such a lasting impact in articulating the public's visceral fears of scientific and technological innovation. The pejorative prefix 'Franken-' has taken on a life of its own, attaching itself to many areas of technological innovation that outpace our comfort zone, including human enhancement,[1] artificial limbs[2] and artificial intelligence (AI).[3]

So long as the general public's views of these technologies are colored by the Frankenstein myth, this technology and its broad applicability can be stymied by unfounded fears and misunderstandings that could result in bad law. That's not to say that there are not real ethical and/or legal concerns associated with the growing introduction of AI machines into society. In fact, the growing pervasiveness of artificial intelligence and smart artificial limbs can have real life consequences in even the heady areas of criminal law, as will be discussed herein. To paraphrase the World Economic Forum: "There has never been a time of greater promise, or one of greater potential peril."[4]

The paper's goal is to counteract the potentially negative association with Frankenstein's monster, principally by raising the issue early before the technology is widely adopted and the issues described herein become entrenched and difficult to deal with. Notably, this paper aims only to raise the relevant issues, such that society can begin thinking about these concerns in a conscientious and forward looking manner, rather than waiting for the knee-jerk response to a new frightening monster. Moreover, rather than shoehorning imperfect solutions into this nascent technology's still unknowable interaction with criminal and other areas of law, this paper purposely leaves many of the especially challenging regulatory decisions outside of the scope of this short analysis.

2. AI and BMI: the problem with translating and predicting the brain's intent

One particular exciting area for AI is its use within brain machine interfaces (BMI). While the growing use of BMIs will likely revolutionize the usefulness and adaptability of assistive biomedical and rehabilitation devices for the disabled (and even the non-disabled), their incorporation into the field of biomechatronics raise a number of problematic concerns, particularly in the areas of criminal and tort law. Other grave concerns, including the potentially even more disconcerting issues of malicious hacking [5] [6] are beyond the scope of this paper.

Succinctly, using BMI technology, prosthetic devices have been designed to read and translate neural impulses from the brain or from nerve endings into actual interactions between the 'user' and the environment, typically through some form of movement by the prosthetic. In the case of BMI-mediated prosthetics, BMIs can be used to control, to varying degrees, the actions of those prosthetics using, for example, neural pathways formerly used for controlling the lost or original limb.

BMIs are often designed to wholly ignore, or even act against, seemingly rogue brain signals (false positives) received from the user. In some instances, this may be due to a calculated conjecture that those neural signals were incorrectly translated, received, or simply noise and do not reflect the true desire of the user. Here, in this instance, the AI-mediated BMI augments the user's control, making true (ok) or false (potentially problematic) assumptions about the user's intentions, and, importantly, carrying out those assumptions, irrespective of the received signal.[7] This implementation is, to some degree, unremarkable: all interactions based on deciphering neural activity are inherently based, to varying degrees on assumptions. In a best case scenario, a BMI-prosthetic system is designed to get the user's intentions right most of the time. In more troubling scenarios, there is the possibility that the BMI may be poorly designed, created with faulty ethical frameworks, or possibly designed with a different value system than the user.[8]

This paper looks to examples in criminal law and tort, particularly the areas relating to property destruction, assault, battery, and even murder where it is conceivable that a single rogue action can lead to a terrible result. These concerns are much less likely to arise when a series of discrete actions is necessary for a bad result, for example, theft.

While the authors acknowledge that these aforementioned resulting unintended actions may occur only on rare occasions, nevertheless, this limited control by an AI could be ominous, resulting in a real-life Franksteinian-like situation where the public perception quickly becomes that the 'monster', no longer under the control of humans, and, in some sense, in control of the human, can create intended or unintended havoc: an AI-mediated prosthetic could damage property or commit an assault against another person, ostensibly against the will of the prosthetics user.

Drilling down, a specific simple example of a user's unintended but potentially criminal or tortious action, could include the following scenario: a user might intend to lift his hand and move it to the right. The BMI might misinterpret this intention and move the hand to the left, the misinterpretation due either to signal noise, the assumption that the intent to move to the right was noise, or any other number of potential problems that may occur at the unnatural interface between biological and digital worlds. If the move to the left results in a tortious or criminal action, the law needs to know if the individual himself is at fault, or if some other entity can be found to be wholly or partially at fault.

The misreading of a cue is not the only way an AI and BMI-mediated prosthetic might be seen by the public as a criminal monster: artificially intelligent machines are typically designed to learn and adapt from their environment. Researchers have shown that AI machines associated with prosthetic limbs can learn and adapt such that they can predict a desired movement by the user, based on immediately preceding movements.[9] For example, a user may typically make a series of movements: A, B and C, where C always follows A and B. Conceivably, the BMI algorithmswill recognize these sequential movements, and potentially even anticipate C following every combination of A and B. The benefits to this shortcut are clear: less mental strain on the user to get to action C, as described herein.

A situation may arise, however, where the user of the prosthetic wants to do a novel sequence of movements: A, B and D. The BMI, however, may erroneously recognize the intent to do D as noise, or, alternatively, before the mental impulses are generated by the user to do D, the BMI instructs the prosthetic to do predicted movement C, wherein C is not only the unintended movement, but also causes a tort or criminal harm, for example, striking an individual or causing harm to property.

The fact that predictive algorithms would be implemented, these potential harms notwithstanding, is actually not surprising. Users of BMI prosthetics have indicated that the necessary mental focus for requisite neural activity to actuate the prosthetic can be mentally exhausting.[10] [11] As such, the creation of shortcuts to make the use of prosthetics less stressful is likely, if not probable. In many instances, these uses of AI technology will be helpful in making prosthetics easier to use. Thus, while real-time prediction learning and other emergent behaviors can be especially helpful for the individual using a complicated prosthetic limb with multiple degrees of freedom, eventually, if incorporated into the actual control of all devices, it raises questions as to who, in the case of a crime, actually moved the crime-causing limb, the user or a semi-autonomous software program that predicted and followed through with the criminal action.

In simple case of non-BMI or AI robotics the manufacturer is typically at fault, perhaps even subject to strict liability, depending on the jurisdiction. In contrast, in AI-mediated prosthetics, the assignment of blame and punishment is not clear. It is unlikely that a court will find that the software engineer or the manufacturer, unless malevolent, would be clearly at fault. This is particularly the case, as the law transitions to treating an AI as a legal person unto itself, for example in the case of autonomous vehicles wherein the AI is treated as a driver under California law.[12]

AI-mediated BMIs are not the only BMI area of growing concern for criminal law. Researchers have recently found that to avoid jerky and/or delayed movements of a prosthetic device mediated through a BMI, users could have a BMI (notably, not necessarily an AI BMI) implanted into the brain's posterior parietal cortex (PPC), an area of the brain thought to be responsible for movement mapping and planning and other subconscious and/or preconscious thought.[13] This technology has the ability predict and trigger actions, based on the subconscious planning, even before the user consciously knows that they are going to make them,[14] raising non-trivial concerns regarding the extent of the user's free will vis a vis the control of their prosthetic limb. In this usage, a user need only mentally plan to move their arm from point A to point B for the resulting desired prosthetic action, rather than the more challenging option of mentally

considering each successive movement necessary for the travel from A to B. However, if the planning stage occurs in the subconscious or preconscious area of the brain, the arm may move prior to the user's conscious appreciation of that movement. Pushing on the example above, a user may find themselves at or on their way to point B prior to the development of a conscious desire to end up at point B. The mechanics of this concern are discussed below.

3. Free Will and Bereitschaftspotential

With the continuing interest in understanding the complexities of the brain,[15] there has been a resurgence of research in the area of free will, particularly in light of our evolving understanding of neuroscience.[16] In general, that we all subscribe to some concept of free will is essential to the appreciation of ourselves as a unique species, and more pedestrianly and specifically relevant here, as an arguably key component of the universal relationship between crime and its subsequent punishment in modern society, [17] if not an actual legal requirement within the criminal justice system:[18] [19]"The legal and moral traditions of the western world require that those who, of their own free will and with evil intent … commit acts which violate the law, shall be criminally responsible for those acts."[20] Thus, simplistically, if we do not freely will our actions, why should we be responsible or punished for those actions: "Legal responsibility, be it civil or criminal, implies freedom. To make a contract in law requires the free acts of the participants, and the doing of a socially reprehensible act is legally excusable, where the actor was not a free agent…"[21]

However, continued research continues to erode earlier broad conceptions of the colloquial understanding of free will. [22] One particular area of recent interest has focused on the sliver of time wherein the conscious brain can override what has been often found to be the initial unconscious decision to do something[23] --for example to make a movement--[24] that unconscious decision[25] as indicated by the start of the Bereitschaftspotential[26] or readiness potential.[27]

More specifically, in support the idea of free will, researchers continue to attempt to tease out whether an actor can consciously cancel an unconsciously initiated action, that decision to do the action indicated by the rise of the readiness potential, and as directed by the unconscious brain. If human actors cannot intervene in the cascade of neuronal activity, then, as the argument suggests, we do not have the free will that we all think we do. If this is the case, then the free will underpinnings of criminal law rest uneasily on untenable legal fictions and unsupported folk psychology.[28] However, if humans have the ability to cancel those actions before they are effected, then we retain some aspect free will, and, importantly, its associated societal constructs, including, relevant here, in criminal law.

Some of the most current research suggests that this point of no return for a readiness potential, i.e., after which the unconsciously initiated action can no longer be interrupted by conscious decision, is at most a couple of hundred milliseconds prior to the actual movement, after that time interval we lose our ability to consciously intervene. [29] While these results are not universally accepted,[30] if they are correct, much of society retains sufficient free will to be liable for their criminal actions. One concern of this paper is a small but growing area where this may not be the case: BMI and AI-BMI-mediated prosthetics.

4. Free Will and Criminal Law

In the area of criminal law, we rely on the legal assumption that a guilty criminal is responsible for his voluntary criminal actions and their consequences,[31] and that the criminal conducting the criminal act has both cognition and volition regarding that act. A criminal lacking in cognition or volitional capacity regarding the criminal act may have a legal defense for their actions: "*Actus non facit reum nisi mens sit rea*"[32] Loosely, an action cannot make a person guilty unless that person also possess a criminal mind.

Succinctly, criminal law requires that any liable guilty action include both criminal act and a criminal intention: It is a "basic principle that [a] wrongdoing must be conscious to be criminal [….] this principle is as universal and persistent in mature systems of law as belief in freedom of the human will and a consequent ability and duty of the normal individual to choose between good and evil [...] The central thought is that a defendant must be "blameworthy in mind" before he can be found guilty, a concept courts have expressed over time through various terms such as *mens rea*, scienter, malice aforethought, guilty knowledge, and the like.'[33]

As a statutory element of a criminal offense, the term mens rea is often narrowly construed as the requisite mental state required to be liable for the particular offense, as defined in that instance by the statute or the common law. While it can have a number of particular meanings including: knowingly, willfully, negligently, and recklessly, each meaning requires conscious thought. As per the Model Penal Code: a person cannot be convicted of an offense unless he acted "purposely, knowingly, recklessly or negligently … with respect to each element of the offense."[34]

In conjunction with this mens rea, crimes must also include another component, actus reus, a voluntary act that causes a social harm. Notably, while most jurisdictions do not necessarily include the voluntary nature of the action as a distinct requirement of the criminal act within their criminal statues, in the United States, the voluntary element, as defined by the Model Penal Code[35] is supported by common law and Supreme Court precedent,[36] and has been suggested to even be a constitutional requirement for finding criminal guilt.[37]

While there are many meanings of the term voluntary, the classical usage is as defined by the eminent Supreme Court jurist, Oliver Wendell Holmes as a willed contraction of a muscle,[38] or as Professor Sanford Kadish described, as something more than a "mere event brought about by physical causes which happen to involve a human body…"[39] The difficulty in finding the proper definition of actus reus notwithstanding, most will agree on the negative: that an act that is sufficiently involuntary is absolved from criminal responsibility. [40]

Returning to the idea that most individuals can, however minimally, consciously intervene in the neural cascade process that results in an action from an early unconscious intent, in some instances current efforts in BMIs may have short-circuited the ability to consciously intervene. As such, brain machine interface technology can create a situation where we lack one or both of the criminal intent and the volitional criminal action, either because the AI is the actor with the intent, having translated earlier preferences into acted upon predictions, as describe in the sections above, or because a BMI (AI-mediated or otherwise) interfaces with a prosthetic upstream of the conscious intervention point, i.e., at the PPC, relieving all actions mediated by this BMI from the last shred of free willed control.

As such, disturbingly, a BMI implanted in the PPC may likely read and implement neural impulses at a preconscious state in the readiness potential cascade. By taking its direction from the brain prior to either a conscious decision, or prior to the opportunity for the conscious brain to prevent an unconscious decision, these BMIs are effectively relieving the prosthetic user of not only their free will to control their prosthetic based on a conscious decision, but also their ability to make conscious voluntary decisions to stop their prosthetic device, and throwing into doubt whether any criminal act conducted by the user via their prosthetic has the requisite elements of a voluntary conscious crime. Like Frankenstein's monster, it may seem to many that the user of a PPC BMI has lost control of their creation.

5. Artificial Intelligence and Criminal Liability

If the AI BMIs (described herein) are the actors with the requisite intent in the hypothetical where an AI-mediated BMI commits a violent crime, can they be legally found guilty of that crime?

Surprisingly, there is relatively little written on the criminal liability of artificial intelligent machines. Perhaps most prominently, Hallevy has outlined the three seemingly obvious options for criminal liability for an artificially intelligent agent. The manufacturer can be held wholly liable, the user may be wholly liable, or the AI itself could be held accountable for its actions.[41] Outside of exonerating other parties, it remains unclear as to what it would mean for an AI to be criminally accountable, with perhaps the closest, but yet still sorely imperfect analogy being a corporation. In addition to Hallevy's formulations, there may be various mixtures of liability and guilt, perhaps even depending on the nature of the crime, the shared autonomy at the moment of the crime, and other variables.

What about the user? Many jurisdictions, including the United States, allow for defenses that limit the individual's blameworthiness. Typically these defenses speak to the individual's capacity to have the requisite intent, including legal insanity, being underage, being unconscious, or extenuating circumstances

such as duress. Some of these defenses belong to the class of non-insane automatisms, such as sleepwalking. Prominently, the Canadian Supreme Court acquitted Mr. Parks of murdering his mother-in-law, after having stabbed her multiple times ostensibly while he was asleep.[42] Like the as-of-yet-untested defense of an uncontrollable alien limb[43], individuals lacking conscious control over a criminal limb or body, may not be held liable for the actions of their limb or body.

There are other similar instances wherein the law recognizes the lack of human control over our bodies and has allowed that lack of control to be a defense against criminal liability. Typically, if an individual loses control over their actions as a result of a prior action that could knowingly lead to the criminal action, the courts will not find a defense. This is best explicated by Justice Humphreys, in Kay v. Butterworth, who ruled in the case of a tired driver falling asleep at the wheel and running over a column of American GI's: "If a driver allows himself to be overtaken by sleep while driving, he is guilty, at least, of the offence of driving without due care and attention because it is his business to keep awake. If drowsiness overtakes him while driving, he should stop and wait until he becomes fully awake. Mr Kay should have known that drowsiness was overtaking him, and the case is too clear for argument."[44]

Thus, in the argument as to whether a user can be liable for the actions of their BMI-mediated prosthetic, courts have to determine the likelihood of an unintended criminal action. Looking to case law, an assault as a result of hypoglycemia, was ruled criminal liable, as the defendant knew or should have known what could result by allowing himself to come into this state. In the alternate, a criminal action resulting from an undiagnosed cerebral tumor was not criminally liable.[45] More specifically, in *Bratty v AG for Northern Ireland* (1963), one of the leading cases on the subject matter, Lord Denning Bratty ruled, "…'automatism' - means an act which is done by the muscles without any control by the mind such as a spasm, a reflex action or a convulsion; or an act done by a person who is not conscious of what he is doing . . . [But] in the criminal law an act is not to be regarded as an involuntary act simply because the actor does not remember it... Nor is an act to be regarded as an involuntary act simply because the doer could not control his impulse to do it. Rather, non-insane automatism, requires an external factor that could not be predicted, including: a person who has been struck by a stone or overcome by a sudden illness , or when the car has been put temporarily out of his control owing to his being attacked by a swarm of bees..."[46] The hard question here, is where do BMIs and AI-mediated BMIs fall.

Arguably, AIs have reached the point where we cannot expect to know every conceivable action by the AI, thus pushing AIs more into the realm of the unpredictable and defensabe. To put this in all perspective: Google recently developed an AI machine, AlphaGo, designed to beat the world's best in the game of Go using a deep neural net that learned by, among other things, playing experts, but also playing itself. By learning from a machine, the AI obtained a unique advantage. [47] In what is now infamously known as 'Move 37', Google's AI made an unlikely, and at the time thought to be an egregiously mistaken move. Although, the move confounded the leading Go players at the time, arguably the move won the game for Google. Notably, it was not a move that would have been programmed by AlphaGo's handlers, or any other professional Go player. It was AlphaGo's move, the result of the complex neural network that learned the move on its own through developing its own novel strategies and made a calculated decision to execute that particular move given a multitude of alternative options.[48]

Pushing the Go example further, we are likely not yet at the point where AIs have the necessary consciousness for themselves to be liable for criminal actions: the same AI that resulted in Move 37, also resulted in AlphaGo missing move 78 —described as a uniquely human move—a disaster that led to AlphaGo losing that game. [49] That move, some argued, showed that there was something that remains uniquely human in the game, and that the machine cannot yet attain.

Analogizing AlphaGo's moves with the aforementioned BMI-AI-mediated criminal action, we might also come to similar conclusions that the criminal action was unpredictable given the provided software and inputs and that neither the user of the prosthetic, nor its coder should be held criminally liable: just like Google's programmers could not take credit for coming up with Move 37, an AI's engineering team, nor the prosthetic's user who consciously agreed to use the device, might similarly not be credited with a criminal action. Further, like Move 78, we can expect that AI's still lack something uniquely human and perhaps AIs and other software cannot yet be held liable for their criminal actions.

6. **Balancing Public Safety and Privacy**

Some may argue that this conclusion is highly problematic. Essentially, we cannot find Dr. Frankenstein guilty for his creation of the monster, as the resulting criminal actions cannot be ascribed to the humans involved, nor could they have been predicted. Similarly, the monster cannot be held liable for the criminal actions, as it is not yet sufficiently human to be liable for criminal actions. As a result, people with BMI-mediated prosthetics will always have a viable defense against crimes. An easy solution might be to incorporate a reporting function into the BMI, to determine just what neural activity resulted in the offending prosthetic activity, and whether that offending prosthetic activity can then be ascribed to a guilty user or a non-guilty prosthetic. Its simplicity notwithstanding, such a system will likely never be implemented given the gross privacy violations that it entails. Fortunately, at least in the meantime, the criminal law system, for all its deficits, might still be able to figure out where to assign blame from the myriad types of evidence at its disposal.

7. Conclusions.

Given the emergent and unpredictable nature of AI, the incorporation of advanced AI technology into prosthetic devices will raise non-trivial issues in ascribing criminal guilt to either the AI itself, the user, or a third party. In addition, the use of BMI-PPC implants with or without AI also raises similar concerns with regard to ascertaining guilt to seemingly criminal actions mediated by the prosthetic device, particularly given our current understanding of free will and volitional conscious acts.

Importantly, this isn't just new technologies raising old questions. Unlike the less than useful defenses of intoxication or hypnosis wherein the criminal is still held liable because they voluntarily put themselves into a situation where they knew that they would lack voluntary control, it's hard to draw correlations to persons with disabilities who don't see their prosthetic as a Frankenstinian monster, but rather appreciate the promises of a smart prosthetics in their lives.

Eventually, governments and the courts will need to balance the likely minimal risk of a tort or criminal action due to the circumstances set out above with the probably greater likelihood that such a liability might substantially chill innovation in this area, both because developers of the technology will be unwilling to take on the risk that they might be held liable, and also because the users themselves, even if found not criminally liable, may retain some moral objections to being involved in a crime.

Given these concerns, perhaps it might be useful for an insurance fund to be developed that could make the unlikely victims of unintended actions caused by AI-mediated BMIs whole. And, associated with the fund, legislation and regulation that also limits the criminal and civil liabilities of users and developers could be created. This won't address all the relevant concerns, including the possibility that an individual with a BMI-mediated prosthetic will intentionally cause a harm knowing that they can blame their machine. Here, however, we might put at least some of our trust in the courts and the legal system, to tease out the underlying liability and blame, irrespective of the machines involved.

Similarly, the public will eventually appreciate that the Frankenstein metaphor is not apt for BMI-mediated prosthetics. In Shelly's version, the monster cannot be controlled by the humans, but here, the humans will likely always retain some, if not all control. Nevertheless, scientists and those in this technological area ought to be vigilant in not allowing the Frankenstein metaphor to attach to these devices, as not only is the analogy inapt, it will likely be a huge disservice to the advancement of this very powerful and useful innovation.

[1] Lin, Patrick, and Fritz Allhoff. "Untangling the debate: The ethics of human enhancement." *Nanoethics* 2.3 (2008): 251-264.
[2] Alice Rawsthorn "Messing With Mother Nature" New York Times JULY 8, 2012
[3] Lehman-Wilzig, Sam N. "Frankenstein unbound: towards a legal definition of artificial intelligence." *Futures* 13.6 (1981): 442-457.
[4] World Economic Forum, "The Fourth Industrial Revolution: what it means, how to respond," available online at https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/
[5] Bertolt Meyer: 'Ethical questions are looming for prosthetics' Wired, 30 August 2013, available online at http://www.wired.co.uk/magazine/archive/2013/09/ideas-bank/now-we-need-to-talk-about-our-bionic-future
[6] Zhang, Meng, Anand Raghunathan, and Niraj K. Jha. "Trustworthiness of medical devices and body area networks." *Proceedings of the IEEE* 102, no. 8 (2014): 1174-1188.
[7] Haselager, Pim. "Did I do that? Brain–computer interfacing and the sense of agency." *Minds and Machines* 23.3 (2013): 405-418.
[8] Pistono, Federico, and Roman V. Yampolskiy. "Unethical Research: How to Create a Malevolent Artificial Intelligence." *arXiv preprint arXiv:1605.02817* (2016).
[9] Pilarski, Patrick M., Travis B. Dick, and Richard S. Sutton. "Real-time prediction learning for the simultaneous actuation of multiple prosthetic joints." *Rehabilitation Robotics (ICORR), 2013 IEEE International Conference on*. IEEE, 2013.
[10] Rosen, Meghan. "Mind to motion: Brain-computer interfaces promise new freedom for the paralyzed and immobile." *Science News* 184.10 (2013): 22-26.
[11] Hildt, Elisabeth. "Brain-computer interaction and medical access to the brain: individual, social and ethical implications." *Studies in Ethics, Law, and Technology* 4.3 (2010).
[12] Shepardson, David and Lienert, Paul Exclusive: In boost to self-driving cars, U.S. tells Google computers can qualify as drivers, Reuters Wed Feb 10, 2016 available online at http://www.reuters.com/article/us-alphabet-autos-selfdriving-exclusive-idUSKCN0VJ00H
[13] Thomson, Helen. "I think, therefore I can." *New Scientist* 226.3023 (2015): 8-9.
[14] Aflalo, Tyson, et al. "Decoding motor imagery from the posterior parietal cortex of a tetraplegic human." *Science* 348.6237 (2015): 906-910.
[15] Markram, Henry. "The human brain project." *Scientific American* 306.6 (2012): 50-55; Bargmann, Cornelia I., and William T. Newsome. "The Brain Research Through Advancing Innovative Neurotechnologies (BRAIN) Initiative and Neurology." *JAMA neurology* 71.6 (2014): 675-676.
[16] Gazzaniga, Michael S., and Megan S. Steven. "Neuroscience and the law." *Scientific American Mind* 16.1 (2005): 42-49.
[17] Focquaert, Farah, Andrea L. Glenn, and Adrian Raine. "Free will, responsibility, and the punishment of criminals." *The Future of Punishment* (2013): 247-274.
[18] *Morissette v. United States*, 342 U.S. 246, 72 S. Ct. 240, 96 L. Ed. 288 (1952); *Smith v. Armontrout*, 888 F.2d 530 (8th Cir. 1989); Cotton, Michele. "Foolish Consistency: Keeping Determinism out of the Criminal Law, A." *BU Pub. Int. LJ* 15 (2005): 1.
[19] But c.f., Dubljević, Veljko. "Autonomy in neuroethics: Political and not metaphysical." *AJOB Neuroscience* 4, no. 4 (2013): 44-51; Morse, Stephen J. "The non-problem of free will in forensic psychiatry and psychology." *Behavioral sciences & the law* 25, no. 2 (2007): 203-220.
[20] *Durham v. United States*, 214 F.2d 862 (D.C. Cir. 1954).
[21] Newman, Lawrence, and Lawrence Weitzer. "Duress, free will and the criminal law." *S. Cal. L. Rev.* 30 (1956): 313.
[22] Haggard, Patrick. "Human volition: towards a neuroscience of will." *Nature Reviews Neuroscience* 9.12 (2008): 934-946; Greene, Joshua, and Jonathan Cohen. "For the law, neuroscience changes nothing and everything." *Philos Trans R Soc Lond B Biol Sci* 359.1451 (2004): 1775-85.
[23] Libet, Benjamin (1985). "Unconscious cerebral initiative and the role of conscious will in voluntary action" The Behavioral and Brain Sciences 8: 529–56
[24] Uithol, Sebo, and Aaron Schurger. "Reckoning the moment of reckoning in spontaneous voluntary movement." *Proceedings of the National Academy of Sciences* (2016): 201523226.

[25] J.A.V. Bates Electrical activity of the cortex accompanying movement J Physiol, 113 (1951), pp. 240–257
[26]H.H. Kornhuber, L. Deecke Hirnpotentialänderungen beim Menschen vor und nach Willkurbewegungen, dargestellt mit Magnetband-Speicherung und Ruckwartsanalyse Pflugers Arch, 281 (1964), p. 52
[27] Soon, Chun Siong, et al. "Unconscious determinants of free decisions in the human brain." *Nature neuroscience* 11.5 (2008): 543-545.
[28] Morse, Stephen J., and Adina L. Roskies. "A primer on criminal law and neuroscience." (2013).
[29] Schultze-Kraft, Matthias, et al. "The point of no return in vetoing self-initiated movements." *Proceedings of the National Academy of Sciences* (2015): 201513569.
[30] Verbaarschot, Ceci, Jason Farquhar, and Pim Haselager. "Lost in time...: The search for intentions and Readiness Potentials." *Consciousness and cognition* 33 (2015): 300-315.
[31] *United States v. Grayson*, 438 U.S. 41, 98 S. Ct. 2610, 57 L. Ed. 2d 582 (1978)(“ A universal and persistent foundation stone in our system of law, and particularly in our approach to punishment, sentencing, and incarceration, is the belief in freedom of the human will and a consequent ability and duty of the normal individual to choose between good and evil.)
[32] *People v. Vogel*, 46 Cal. 2d 798, 299 P.2d 850 (1956).
[33] *Elonis v. US*, 135 S. Ct. 2001, 575 U.S., 192 L. Ed. 2d 1 (2015).
[34] Model Penal Code §2.02
[35] Model Penal Code §2.01
[36] *Robinson v. California*, 370 U.S. 660, 82 S. Ct. 1417, 8 L. Ed. 2d 758 (1962); *Powell v. Texas*, 392 U.S. 514, 88 S. Ct. 2145, 20 L. Ed. 2d 1254 (1968).
[37] Farrell, Ian P., and Justin F. Marceau. "Taking Voluntariness Seriously." *Boston College Law Review*, (2013): 13-25.
[38] Holmes, Oliver Wendell. *The common law*. Harvard University Press, 2009.
[39] Kadish, Sanford H. "Excusing crime." *California Law Review* 75.1 (1987): 257-289.
[40] Goldstein, Abraham S. "Conspiracy to defraud the United States." *The Yale Law Journal* 68.3 (1959): 405-463.
[41] Hallevy, Gabriel. "Criminal Liability of Artificial Intelligence Entities-From Science Fiction to Legal Social Control, The." *Akron Intell. Prop. J.* 4 (2010): 171; Hallevy, Prof. Gabriel, The Criminal Liability of Artificial Intelligence Entities (February 15, 2010). Available at SSRN: http://ssrn.com/abstract=1564096 or http://dx.doi.org/10.2139/ssrn.1564096
[42] *Regina v. Parks*, 95 D.L.R.4th 27, 75 C.C.C. (3d) 287 (1992).
[43] Biran, I., and A. Chatterjee. "Alien hand syndrome." *Archives of Neurology* 61.2 (2004): 292-294.
[44] *Kay v. Butterworth*, 173 L.T. 191, 61 T.L.R. 452 (1945).
[45] Charlson, R v [1955] Barry J
[46] Hill v Baxter [1958]
[47] Kasparov, Garry. "Game changers." *New Scientist* 229.3063 (2016): 26-27.
[48] Cade Metz How Google’s AI Viewed the Move No Human Could Understand, Wired, March 14,2016. Available at http://www.wired.com/2016/03/googles-ai-viewed-move-no-human-understand/
[49] Metz, Cade, In Two Moves, Alphago and Lee Sedol Redefined the future, Wired, March 16, 2016 available online at http://www.wired.com/2016/03/two-moves-alphago-lee-sedol-redefined-future/