Children surviving neural injuries face challenges not seen by their adult counterparts, namely that they experience neural injury before reaching neurodevelopmental maturity. Neural prostheses offer one possible path to recovery, along with the potential for functional outcomes that could exceed expectations. Although the first cochlear implant was placed more than fifty years ago, the field of neuroprosthetics is still relatively young. Several types of neural prostheses are in development stages ranging from animal models to (adult) human trials. In this paper, I discuss how neural prostheses may assist recovery for children surviving neural injury. I argue that approaching the use of neural prosthetics in children with considerations derived from transhumanism alongside traditional bioethics can provide an opportunity to reframe adult-focused ethics toward a child/family focus and to strip away the prejudicial metaphor of cyborgization.

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In literature and film, neural prostheses often receive a negative image, entangled in ideas of cyborgization and the creation of a monstrosity. They may exist as enhancements in a dystopian future, as in William Gibson's *Neuromancer* (1984). In Stephenson and George's *Interface* ([1995] 2005), a neural prosthesis initially appears to be used to regain function after a stroke, but is in fact used to control an individual in order to sway politics. A recent film of Richard Condon's novel *The Manchurian Candidate* (Demme 2004) follows a similar overall premise (an earlier movie version, Frankenheimer 1962, incorporates brainwashing rather than neural prostheses). However, a more positive take on neural prostheses was presented in the television series *The Six Million Dollar Man* and *The Bionic Woman*, in which amazing increases in physical capabilities were put to use to save humankind and defeat evil.

All these cases are fiction, but neural prostheses are real. Over the past fifty years they have moved from possibility to reality for hundreds of thousands of individuals (cochlear implants). As technology improves, they will become applicable for ever more uses, including, for example, the restoration of hippocampal function via a biomimetic device (Berger et al. 2012).

Children surviving neural injuries have deficits in cognitive functioning (Gerrard-Morris et al. 2010) that vary based upon the anatomical location of injury, the child's age at the time of injury, and the intensity of the injury. Current rehabilitation efforts offer only modest compensation (Galvin and Mandalis 2009), perhaps because the assembly of cognitive processes through human development is not yet well-identified (Horton et al. 2010; Luna 2009; Luna et al. 2010) and the extent of neuroplasticity in childhood and adolescence, especially after neural injury, is unknown (Stiles 2000; Stiles et al. 2005). In this paper, I will first briefly review neural prostheses as they exist now, identify developmental areas that provide challenges, and discuss applications for children with neural injury. I will then introduce transhumanism and show how transhumanism and traditional bioethics might be applied together to benefit children after neural injury. I argue here in favor of the use of neural prostheses in general, and particularly for children who have sustained neural injury. The union of transhumanism and bioethics can reframe this discussion by removing the metaphor of cyborgization and refocusing bioethics in this population from *the adult* to *the child/family*.

Neural prostheses

Neural prostheses include a variety of central nervous system implants that either provide mechanical stabilization and anchor for biological transplants or engage in electrical communication (recording, providing input, or both) for cognitive or other functional effects. Like other medical devices, they experience incremental design advances and are subject to regulation which begins with testing in animal models. Regulation generally disfavors testing in pediatric populations except for child-specific medical conditions or when no approved treatments are available.

Types of neural prostheses

There are several categories of neural prostheses, with some overlap. One goal for neural interface systems is to provide a link to the outside world (Hatsopoulos and Donoghue 2009), which was accomplished with the first successfully attempted neural prosthesis more than fifty years ago, a cochlear implant (Djourno et al. 1957). Thus far, most published work regarding neural prostheses concerns cochlear implants, and, as of December 2010, more than 219,000 had been implanted into adults and children around the world (National Institute on Deafness and Other Communication Disorders 2011). A successful implant is made possible only by high-quality hardware and software, together with the ability for neuroplasticity evident in human brains (Fallon et al. 2009).

Operative neuromodulation is the use of an implanted device to produce an altered electrical or chemical signal transmission in the nervous system in order to achieve a therapeutic effect (Sakas et al. 2007). Prostheses that take advantage of operative neuromodulation include deep brain stimulation (DBS; currently approved in the United States for Parkinson's disease and other movement disorders, major depressive disorders, and seizure disorders, and for some chronic pain sufferers), sensory prosthetics (e.g., cochlear implants, retinal implants currently in clinical trials), functional electrical stimulation (primarily to restore function from paralysis), and others (e.g., stimulation of occipital and supraorbital nerves for the abatement of cluster headaches).

Cognitive neural prostheses are implanted devices that are intended to restore function to any cognitive process, including those processes that could control a functional prosthetic limb (Andersen et al. 2010). Operationally, these can be considered part of a brain-computer interface in which the prosthesis allows communication between the individual's brain and an exterior device that compensates for lost function. This external device can be attached to the person or be a separate piece of equipment, such as a robotic arm or computer. At least one company has established such a system with humans (Simeral et al. 2011; BrainGate 2012), although development of functionally innervated systems that can control neuromotor

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prostheses is in its infancy (Serruya and Kahana 2008).

Developmental challenges for neural prostheses

Neural prostheses are limited by the current state of technology and neurophysiological understanding. Suboptimal design of materials limits interaction with neural tissue and often leads to fibrotic capsule formation (Poole-Warren et al. 2010). Even without capsule formation, it is difficult to maintain high-signal fidelity of the electrode-tissue interface over long periods (Konrad and Shanks 2010). As interface systems improve, increased device efficacy will result in improved functional recovery (Wang et al. 2010).

Suggestions for improved brain-implant interfaces include seeding the prosthesis with neural progenitor cells (Azemi et al. 2010). Kim and colleagues (2010) have created non-invasive, silk-based (and dissolvable) platforms for use with ultrathin electronics that conform to neural surfaces. A three-dimensional electrical interface that allows regenerating axons to grow through and around microchannels has also been created (Benmerah et al. 2009). The combination of cognitive- and motor-based approaches within one system may lead to greater benefits for individuals (Pesarad et al. 2006) as, ultimately, the therapeutic goals of neural prostheses include restoring cognitive functions and/or augmenting what is present after injury or disease (Serruya and Kahana 2008). While several challenges remain, advances have been made with adult trial participants.

Children surviving neural injury

Children surviving neural injury include those with traumatic brain injury, brain tumors (benign and malignant), and other non-traumatic injury (e.g., hypoxia, infection, stroke, substance abuse, seizure disorders). Neural injury at younger ages has a more devastating effect upon the development of cognitive control (Anderson et al. 2010), and those surviving brain tumors in childhood are at significant risk for neurocognitive deficits in adulthood (Ellenberg et al. 2009).

Assuming no life-limiting sequelae, children post-neural injury have a potentially much longer period of time than do brain-injured adults in which to experience decreased function, increased dependence, potentially decreased quality of life, and impediments to participation in society. Furthermore, these children have brains that have been injured before reaching neurodevelopmental maturity. Neural prostheses for directed therapeutic compensation of deficits have the potential to mitigate, or even restore, lost cognitive, sensory, and/or motor function in children after neural injury. This restoration then will allow that individual to personally and independently engage with her environment and society on her own terms.

Without intervention, the demands of providing care for these children can last decades, and this burden of care provision (at least in the United States) falls primarily on parents/families. The child's restored ability to attempt a "normalized" development also frees the family members to pursue their own life ambitions, rather than focusing on providing care to a dependent child for the rest of their lives.

The barriers to using neural prostheses in children with neural injury include the prejudicial framing of a human being with a brain implant (cyborgization) as well as the ways in which adult-conjured and framed traditional bioethics provides a disservice to children. I acknowledge that one further barrier might involve reservations about neural prostheses held by certain groups, such as many in the Deaf community who do not understand deafness as a disability requiring medical intervention with cochlear implants, but rather insist that deafness is normal (Swanson 1997). While this view may have relevance to my later arguments concerning sociocultural constructions of normal, its merits generally lie outside the scope of this paper, which concentrates on neural injury in childhood. In the remainder of this paper, I will

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introduce the transhumanist movement and suggest how transhumanism and bioethics might be applied together to benefit children after brain injury.

Transhumanism

Transhumanism is a school of thought that has manifested in various forms throughout history. In 1998, the World Transhumanist Association (WTA) was organized as an international structure and developed both a "Declaration" (2009) and an extensive frequently asked questions (Bostrom 2003). In the latter, *transhumanism* is defined as:

> The intellectual and cultural movement that affirms the possibility and desirability of fundamentally improving the human condition through applied reason, especially by developing and making widely available technologies to eliminate aging and to greatly enhance human intellectual, physical, and psychological capacities. … [It is also] The study of the ramifications, promises, and potential dangers of technologies that will enable us to overcome fundamental human limitations, and the related study of the ethical matters involved in developing and using such technologies. (4)

In 2008, the WTA rebranded itself as Humanity+ (H+), also adopting the "Declaration" and "FAQ". Transhumanism is a human ideology, as there are not yet any significantly transformed humans, or *posthumans* – as opposed to humans who have imagined or begun transforming themselves (Hopkins 2008, 3). Bostrom (2005) recounts a history of transhumanist thought, stretching as far back as the *Epic of Gilgamesh* and other quests for immortality, including those for the fountain of youth and the alchemical search for the philosopher's stone (1-2). While the core of transhumanism includes the investigation of potential states of existence for humans in the future, it also includes recognition and reduction of the potential for risks with technological development; a moral vision that focuses on reducing suffering, preserving life and health, and improving human wisdom;[1] advocacy for the well-being of all life, human and non-human; and sometimes arguments for equitable access to advancing technology (or at least the option to choose such technology) and for allowing individuals to have a personal choice over how this technology directly enables their lives (WTA 2009).

Both within and outside of the "Declaration" and "FAQ," there is much transhumanist discourse relating to all these. Sometimes there is a focus on transhumanist thought as a sort of utopian vision of a more humane form of existence (Bostrom 2008). Sorgner (2009) and More (2010) both discuss similarities between transhumanism and aspects of Nietzsche's philosophy; their approaches display libertarian features not acknowledged as significant by Bostrom. Other transhumanist thinkers advocate caution, suggesting that the advancing technology that offers extensive enhancement may be closer than we think and that the relationship between becoming posthuman and upholding individual rights is more complicated than one might imagine. This is particularly because of vexed issues of identity that might affect the individual, other individuals, and the process of changing a self (Walker 2008). Schneider (2009) discusses the metaphysical problem of personal identity, especially regarding enhancements, and suggests that transhumanism needs to establish a clearer and more defensible conception of personhood.

This, however, is quite a task in the absence of any uncontroversial understanding of what *identity* or *personhood* might really amount to. A good starting place for this discussion might be Glenn's (2003) exploration of how biotechnology is contributing to changes in the traditional (religious, philosophical, and legal) notions of identity/personhood and suggests a balancing approach that places personhood on a continuum.

Transhumanism does attempt to identify possible harms or risks associated with advancing technologies, including the concept of an existential risk, which is "an adverse outcome [that] would either annihilate

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Earth-originating intelligent life or permanently and drastically curtail its potential" (Bostrom 2002, 4). Such risks include nuclear weaponry (especially its proliferation) and many technologies that do not yet exist but are foreseen (e.g., misused nanotechnology, ill-programmed or flawed superintelligence, engineered bioagents), as well as possibilities that are not specifically foreseen (5-13). Bostrom concludes that caution must be exercised as new technologies are investigated and current ones are manipulated.

There are numerous criticisms of transhumanism. Fukuyama (2004) has called transhumanism the world's most dangerous idea, and described it as threatening our "human essence." Others contend that (the eventual) bifurcation of posthumans from humans will lead to enslavement and/or genocide between the groups from either direction (Annas et al. 2002, 162). Transhumanists would agree with these critics that such acts are moral atrocities, but Bostrom (2005, 19) asserts that any such result is an unlikely consequence of germline enhancement for health, memory, or longevity.

Transhumanism already here?

One could say that humans are already in transitioning states, especially with the changes that cosmetic plastic surgery makes possible. Although these might seem superficial, Scott (2009) argues that the use of cosmetic plastic surgery to "cheat Darwin" has greater (interpersonal) ethical implications than just for the individual. Germline genetic changes are not currently taking place, though Tachibana and colleagues (2012) have demonstrated spindle transfer for the first time in humans as a method to replace mutated mitochondrial DNA. The investigators destroyed the resulting embryos at the completion of the experiments. Germline selection, however, is already being utilized through our ability to identify genotypes. One of my orthopedic oncology patients a few years ago had grown up with multiple (hereditary, autosomal dominant) osteochondromatosis. She wanted children, but did not want to chance their suffering through this painful and debilitating disorder requiring multiple surgeries throughout life. With preimplantation genetic diagnosis, she was able to have only those blastomeres implanted that did not contain the undesired genotype, and she now has two healthy and unaffected children.

Another way to view transitioning humans is to consider how technology is embraced when the goal is to decrease suffering or increase quality of life or health. Insulin pumps, cardiac pacemakers, implanted defibrillators, and many other prostheses with therapeutic value can enhance human living. If having control over one's physiological processes constitutes enhancement, then an argument can be made that the use of oral contraceptives to control ovulation is a form of enhancement (Lindsay 2010). Extending that rationale, vaccinations provide artificial immunity to infectious agents that the body has (generally) not yet encountered, an enhancement that prevents disease and premature death. Daniels (2000) discusses the vaccine example as part of a treatment-enhancement distinction based on "normal functioning" and basing "permissibility" on a social justice rationale. But how would "normal functioning" appear after a neural injury in childhood, especially when the individual is still in the process of physiological neurodevelopment? This question remains unanswered. Neural prostheses are viewed thus far as a possible therapy, though one can imagine the technology being used for purposes of enhancement in the future, especially in an individual whose brain is still developing intra- and inter-cortical connections.

Transitioning (enhancing?) the human state of a child after neural injury?

The two primary aspects of transhumanism that apply to the use of neural prostheses for children surviving neural injury include the mitigation of suffering (via therapy) and the potential for enhancement. Many philosophers, bioethicists, and others have debated whether a principled distinction can be made between therapy and enhancement – and if so, where the line might be established. Colleton (2008) understands that there is a distinction between therapy and enhancement and explores this issue by creating definitions of relevant terms based upon those already in existence in state-level statutes in the United States, health insurance company definitions, and pharmaceutical websites. Such an approach,

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though, biases the discussion toward common practice. In the United States, the health insurance companies are payers for therapy (and preventative care), but they will generally pay only for care that is mandated by law (e.g., whatever is deemed to be "medically necessary"), assists in returning an individual to a previous state of health (e.g., an antibiotic regimen), or prevents the individual from reaching a state of ill health (e.g., preventative care, vaccinations). The term "enhancement" is used differently in different circumstances, and the dichotomization of therapy/enhancement is difficult to establish because the discussion relies on the concept of "health" (Bess 2010), something that is itself controversial: what counts as health varies in many ways, depending on the individual, the culture and relevant society, and their extent of medicalization.

It is clear, however, that children surviving neural injury would have therapeutic opportunities with neural prostheses. Rehabilitation or reconstruction might be individually directed and would focus on the mitigation of suffering and the improvement in quality of life. Enhancement with neural prostheses might be possible in the future after certain aspects of the technology (e.g., neural interface systems) are vastly improved and neurophysiological processes are better understood.

If a human being has a neural prosthesis, is that person in a transformational state toward posthumanity? Is that person a cyborg? Does an infant who receives a cochlear implant become a cyborg or something else not-quite-human? Is the answer relative to the individual's conception of identity?

For a child surviving neural injury, would a neural prosthesis only (potentially) restore lost function? In the case of those receiving cranial radiation for brain tumors, would a prosthesis prevent a loss of future function? Or would the prosthesis compensate beyond what that individual's potential would have been without neural injury? Is this an enhancement, and how would one determine that it is an enhancement without defining a person's potential before it is achieved? Does the restoration/enhancement provided by a neural prosthesis mediate (potential) future suffering? Assuming there are no complications related to the prosthesis itself, is the resultant quality of life improved beyond what human beings experience now, or at least beyond what the individual patient would have experienced without injury?

Asking these questions is important before embarking on research with neural prostheses in children with a goal of therapeutic efficacy. One must strongly consider the risks to such a trial, as well as how they are weighed against any foreseeable benefit – in this case restoration or prevention of functional loss, along with potential enhancements; however, it is debatable just what alterations amount to enhancement. In a particular case, it might be imponderable whether a prosthesis would offer enhancement/improvement beyond an individual's projected developmental course (*sans* neural injury). It certainly could provide improvement over the lifespan post-injury; however, investigations in post-natal developmental biology have not revealed how functional neural pathways mature in healthy children and adolescents. The latter point may even suggest that it is premature to embark on a trial of neural prostheses in children. Devices that would offer the best therapeutic benefit should be designed in such a way as to allow for at least an equivalent process that mimics healthy neurodevelopment, but this may not be possible without a solid understanding of what actually constitutes healthy neurodevelopment.

Even seemingly straightforward questions of quality of life can be problematic. For example, many survivors of childhood brain tumors who cannot live independently self-report their quality of life as high when their parents and healthcare providers offer low proxy ratings (e.g., Carpentieri et al. 2003; Kuhlthau et al. 2012). Aside from disagreement on quality of life, one cannot project future changes in quality of life resulting from a medical intervention without first obtaining supportive data, and a blinded randomized controlled trial of neural prostheses in children does not appear feasible.

These questions are complicated especially by our lack of neurophysiological understanding, as well as by sociocultural norms and legal structures surrounding the ethics of research with children. Arguments

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against the use of brain-interfacing prostheses often rely on the premise that personhood is lost (e.g., change in identity) or altered (e.g., cyborgization). These arguments make reference to traditional conceptions of bioethics. However, principlist bioethics, especially the concept of autonomy, is too narrow to address the questions surrounding neural prostheses in children and fails to provide us with a nuanced assessment. Not only are these bioethical concepts constructed from one set of sociocultural norms, but they also are constructed from the perspectives of adults who believe that it is their role to make decisions about who needs protection and how that protection should manifest for individuals younger than a certain number of years. Unfortunately, this is somewhat arbitrary. There is no magical moment that occurs, for example, at midnight on a person's eighteenth birthday suddenly providing her with sufficient insight and ability to make independent decisions for herself.

Discussion

It is important, then, to address the use of neural prostheses in children surviving neural injury with an ethical perspective that can balance the impulsive monster view (cyborgization) with an appropriate incorporation of a child's and her family's perspective. Such a task is difficult given that ethics is typically discussed and understood from an adult perspective, as it has been developed by adults. What element of paternalism is appropriate when considering neural prostheses for brain-injured children is yet to be discussed in the literature. We can, though, readily conceive that a neural prosthesis could benefit a child who has survived neural injury. Once the science has solidified, such that pediatric and adolescent neurodevelopment is better understood, thereby reducing some of the involved risks, ethical arguments might be able to justify the use of neural prostheses in brain-injured children. At that point, schools of thought such as transhumanism, as played out in both academic and popular media, might offer a means by which a society might reframe the so-called cyborgization of a child. What is currently viewed with suspicion, and perhaps as the creation of a monstrosity, might then be seen as a process that benefits the child, her family, and the wider society.

Ethical justifications

Ethical justifications for the use of neural prostheses in brain-injured children are not difficult to conceive should neurophysiological knowledge of neurodevelopment catch up with technological ability. The utilitarian view of ethics might readily accept a pediatric neural prosthesis trial, given that the benefits could include a greater chance for lifelong independence for the child, a family that is freed from a lifetime of supporting a brain-injured child, and a society that would no longer need to contribute to that child's support and would obtain the possible benefit of her social contributions.

One foundation for a deontological view of ethics is Kant's categorical imperative (Kant 1964, 402),[2] which can be practically interpreted as not making an exception of oneself (to whatever duty/rule structure is or has been established). A deontological view generally takes a personal or individual ethical focus – rather than a social or group focus – and uses a duty- or rule-based structure. Compared to the consequentialist approach employed by utilitarians, such a view might demand a more nuanced assessment of the ethics of neural prostheses for young patients.

The requirements of deontological systems of ethics are discussed primarily by and with respect to adults. Again, we must transform an adult-centered, individual ethical perspective into a method that would be appropriate for either the individual brain-injured child or the family unit. In addition to the adult/individual versus child/family focus problem, another difficulty arises in these cases. When a previously normal/healthy child experiences an illness or injury (such as a brain tumor) that fundamentally alters her functional ability, families often reframe how they understand the child (Deatrick et al. 2006). This change in contextual understanding may very well also change the values that the family considers most important, which may then also alter the hierarchy of deontological duties/rules.

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Aspects of utilitarianism, deontology, and other ethical theories are incorporated into the now classical understanding of bioethics: autonomy, nonmaleficence, beneficence, and justice. These principles, as they are called, take as their standard for interpretation the healthy adult human, or at least the adult human without any diminished cognitive function. A child surviving brain injury is generally considered cognitively immature, is below the legally sanctioned age for autonomous decision-making, and has acquired cognitive deficits. Where should the line be drawn when determining when a child can make decisions about her own future as an adult? Why should this decision be made by adults?

Transhumanism + ethics

Transhumanism may be applied alongside more traditional ethical guides in order to reframe how these questions are addressed, although this might only be relevant in practice if those involved accept the values associated with transhumanism. Not all survivors of neural injuries in childhood wish to pursue academic study or even a career. Many are content living a fairly solitary life with their families (though the views of the other family members might vary greatly). Other survivors of neural injury in childhood struggle because they do not have the functional capability to succeed in education, the workplace, or even social environments (Ellenberg et al. 2009). These individuals might like to have the choice to use technology that compensates adequately for the loss of function. From the point of view of transhumanism, this should be a choice available to the individual to make at any time, though how parent/family input would be factored into the decision is unclear. If efficacy and safety were not major concerns, the decision to use the technology would probably take place within families.

Taking a step back from a future with fully available technology, to a time closer to the present with emerging technology, the use of transhumanist thinking alongside traditional bioethics could help reframe the approach to research trials involving neural prostheses in children surviving brain injury. Given informed consent and assent and the support of a multidisciplinary team of investigators, the "possibility and desirability of fundamentally improving the human condition through applied reason" (Bostrom 2003, 4) would unfold simultaneously with investigation for therapeutic benefit. Transhumanism does not seek harm any more than do those seeking or applying therapeutics. Thus investigating the use of neural prostheses in children surviving brain injury can have goals from both transhumanism and traditional healthcare research.

Without intervention, many children surviving neural injury have questionable future competence and autonomy, potentially unable to live independently because of physical or cognitive constraints. With a neural prosthesis, however, who or what is in control? Does the patient maintain control using the prosthesis to compensate for neurological deficits, or is the computer interface directing her decisions, actions, thoughts, etc.? Should this be understood as a question of identity? If so, how much input from the family and parental view of the child's identity should be used when decisions are made about patient care? Or is the question of identity moot, since those suffering neural injury "lose" self-identity (Anderson-Shaw et al. 2010) and then struggle to regain it during recovery (Hoogerdijk et al. 2010)? An individual's identity develops as he or she grows older (especially from child to adult). What may be more relevant to the discussion are questions of autonomy.

Historically, bioethical standards were created in response to injustices that had already taken place (e.g., Nuremberg Code after the Doctors' Trial; Belmont Report after Tuskegee). I would like to think that we as a society now have more ability to judge what issues might be ethically questionable when considering any given research trial. We have an opportunity to address these issues – regarding the use of neural prostheses in general, and their particular use in children – proactively, as the technology and our understanding of pediatric neurodevelopment emerge. Specific research questions might include: How can autonomy be addressed for survivors of neural injury who are children (legally incompetent based

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upon age), potentially cognitively incompetent due to neural injury, and yet have the opportunity to have prosthesis-assisted neural plasticity for potential gain-of-function? How is the appraisal of autonomy altered by the presence of a neural implant? What is the financial commitment over the patient's lifetime for management and maintenance of a neural prosthesis, and will this be burdensome to those with restricted access to either appropriate finances or affordable healthcare? And finally, does this financial commitment for management and maintenance of a neural prosthesis result in less expenditure than a commitment to support the dependent child throughout her lifetime?

Transhumanism can help address some of these questions. One can presume that for the foreseeable future a child will not receive a neural prosthesis unless there is some therapeutic goal associated with the device and there is no primary enhancement purpose, *per se*, to such a device. Transhumanist purposes for technology use include "improving the human condition," and the therapeutic purposes of neural prostheses do not differ so greatly, though the scale of improvement might differ. While an implant's purpose is to allow an individual to regain lost function (e.g., motor control, memory formation), her condition is greatly improved beyond her post-injury functioning. Many of the neural prostheses already in development, however, engage with technology outside of the individual (e.g., robotic limb, brain-computer interfacing) that can provide her with different and sometimes greater capabilities than she possessed pre-injury. The use of neural prostheses creates transitioning states in individuals that should not be viewed as a cyborgization any more than others with different bodies (the injured, ill, or disabled) should have their own conditions contextualized by a sociocultural "normal." By this, I refer to and agree with Lupton's (2003) conclusion that the metaphors we use for conditions different from the norm – especially those that are less understood – reveal social or political anxieties that those creating the imagery desire to categorize and control.

Yes, let us have a focus on caution while proceeding toward some goal (therapeutic or enhancement), but let us do so without stigmatization. In the past, biomedical framings of *bodies that are different* from the medical norm have conceptualized those bodies with negative metaphors. In an ideal future, biomedicine and transhumanism can frame *bodies that are different* as: (a) if you are satisfied with your body, great – if not, change is possible, and (b) the change that you choose occurs outside of oppressive and stigmatizing discourse. Adding transhumanism to the bioethical contextualization for children surviving neural injury will allow us to strip away the prejudicial metaphor of cyborgization, making possible opportunities for therapy or enhancement, as technology allows and as chosen by the individual.

It is not practical to throw traditional conceptions of autonomy aside only when considering children, thus establishing separate autonomy standards based on a developmental age rubric (not to mention the new problems of trying to decide when to switch between standards) would be inappropriate. What may help, though, is the context that transhumanism adds to scenarios involving potential improvements to the human condition. Despite Beauchamp and Childress' (2009) claim that bioethics is based on universal morality (2-5), it primarily reflects the values of a Western, industrialized culture (Weingarten 2011). These values inform how traditional bioethics approaches children and include: children generally cannot make decisions for themselves; someone who is considered a legal guardian for the child must make the final and official decision for her; and since children are considered vulnerable, they need added protections when being considered for experimental situations. Reflecting traditional bioethical values, children are seen as having limitations (e.g., cognitive, physical) when compared to adults.

Transhumanism aims to "overcome fundamental human limitations" and, when added to bioethics, can help to inform discussions centering on children with neural injury. These children will not only develop into adults, but the neural injuries have established limitations in those individuals, limitations that have the potential to be overcome. Transhumanism, when paired with bioethics, removes the value of an *adult-focus* and replaces it with *overcoming limitations in an individual*.

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I agree that protecting the vulnerable is a good idea, and transhumanism does not imply otherwise. Protections can and should remain in place, reframed in the context of limitations: limited cognitive capacity, limited ability to create long-term memories, or limited motor ability. The standards against which these limitations are identified, though, would have to be well-thought out. For instance, as typical human capacities are increased it might not be reasonable to reframe previously "normal" human cognition as a limitation requiring special protections.

Next steps

The most pressing need is more basic science research focusing on pediatric and adolescent neurodevelopment. Without understanding how neural circuitry develops in immature, post-natal humans, we will not be able to develop technology targeted at exploiting these processes.

Meanwhile, more deliberation is needed regarding children and autonomy. Is it possible to have a fully child-centric autonomy? If not, how about a family-centric autonomy? My suggestion to remove the value of an adult-focus and to replace it with *overcoming limitations in an individual* still assumes certain values, particularly that a limitation is negative and overcoming that limitation is positive. While I do not think it possible to have a value-free ethics, are there more appropriate values that could be applied? This may be best addressed by interviewing groups of children who either have or have not participated in research or extensive clinical care.

There is no consensus on whether or not there should be a dividing line between therapy and enhancement, though perhaps the wrong question is being asked. Even considering a bifurcation between therapy and enhancement brings with it qualifications laden with metaphors. Perhaps a more appropriate approach would include abandoning normative conceptions of therapy or enhancement and embracing *bodies that are different*. If all bodies are different, neither therapy nor enhancement has a normative ground from which to judge.

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Notes

1. In some ways, this relates to the transhumanist concept of *superintelligence*, which is an intellect that can outperform the best human brains in every area (Bostrom 2003, 12-14).

2. Pagination refers to the Academy edition.

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