The Binding of Fenrir: Children in an Emerging Age of Transhumanist Technology

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ABSTRACT
The meaning of "children's technology" is poised for imminent and radical change, as a variety of technologies are developed whose goal is to expand or augment the biological limitations of human functioning. These transhumanist *technologies (including sensory augmentation, robotic bodily extensions, brain-machine interfaces, and genetic alteration) pose urgent questions for the community of designers of children's artifacts. This paper discusses the questions that transhumanist technologies raise for children's design specifically; we then present suggested heuristics for design in this new space, and outline plausible research projects consistent with those heuristics.*

Author Keywords
Human augmentation; human enhancement; children's technology; transhumanism.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
For decades now the very idea of "children's technology" has been based on several bedrock assumptions. The first of these assumptions is that the term "technology" refers primarily (if not exclusively) to digital electronics, with an emphasis on computers and communication. The second is that "technology", even under its broadest interpretation, is something *external*, in the surrounding environment of the child. The third is the biological constancy of human beings–and a fortiori, children–over historical time. In short, a typical research project might center around (say) designing a digital artifact to be placed in a classroom (or museum, or child's bedroom), for a child biologically indistinguishable from those in past millennia.

IDC '17, June 27-30, 2017, Stanford, CA, USA © 2017 Association for Computing Machinery. ACM ISBN 978-1-4503-4921-5/17/06…$15.00
http://dx.doi.org/10.1145/3078072.3079744

These assumptions have been so ingrained in the educational technology community for so long that there would seem to be no controversy about these ideas–to question them would be to question the very nature of "technology" and (more disturbingly) "children" and "childhood". We *know* what these terms mean, don't we?

There are growing indications within technological culture that in fact we do not. A steadily increasing attention to technologies that work on a biological level–*internally*, in a sense, rather than externally–needs to be acknowledged and discussed in the context of design for children. The technologies in question are varied–they include sensory extensions, robotic augmentations to the body, techniques for genetic alteration, bodily implants, and brain-machine interfaces, among others. Collectively, these technologies are likely to shift the underlying discussions of children's technologies from a default emphasis on artifacts in the child's environment to artifacts that (potentially) affect the traditional sensory, kinesthetic, and cognitive dimensions of childhood itself.

The current historical moment, then, presents us with the prospect of "transhumanist" technologies–advances meant to venture beyond the evolutionary and biological limits of human nature. As designers, our situation is reminiscent of an ancient story from Norse mythology concerning the character of Fenrir. Fenrir is a wolf of tremendous potential strength and ferocity (he is one of the children of the mischievous god Loki); but as a young animal he is adopted by the Norse gods and treated as a pet, in which role he is largely ignored. Over time, however, the god Odin notices that Fenrir is growing steadily larger; the day-to-day change is imperceptible, but the challenge posed by the adult wolf is soon going to be impossible to meet. The gods' urgent task, then, is to somehow bind Fenrir–to create a leash strong enough to cope with the beast that he will eventually become. [Keary & Keary, 1870]

The community of children's technology design is arguably faced with an analogous task. At this point it is difficult to predict precisely which elements of transhumanist research represent imminent challenges, which reflect longer-term issues, and which are simply futuristic fantasies. It is nonetheless clear that the range and plausible impact of transhumanist technologies are steadily growing, like Fenrir. Much like Odin and his companions in the Norse myth, it is not within our power to kill the beast outright (indeed, there are good reasons why we shouldn't want to do so); but without discussion, we lack even the rudiments of an intellectual "leash" with which to bind the oncoming rush of strange new techniques and philosophical questions.

The remainder of this paper is a discussion of the meaning of transhumanist technologies for the field of children's design. Such issues have, surprisingly, been largely absent from the debates and predictions swirling about transhumanism in general. The time is therefore right–indeed long overdue–for airing the questions surrounding children's lives in an era of transhumanist technology.

TRANSHUMANIST TECHNOLOGIES: A SAMPLER

There is by now a burgeoning literature on human enhancement and augmentation: good overviews include Clark [2003], Barfield [2015], More [2013], and Lilley [2013]. This section provides a necessarily telegraphic sketch of several main lines of current work, and suggests how those might intersect with the field of design for children.

It should be noted by way of preface that there is usually something of a continuum between *prosthetic* or *remedial* technologies and those that are meant to enhance or extend human capacity. A pair of eyeglasses meant to alleviate nearsightedness is clearly the former; but if the glasses are designed to allow the user to "see" wavelengths in both the visible and infrared ranges, they could be described as an enhancing technology. A recurring theme in the literature is that, while remedial technologies are seen as uncontroversial and benign, enhancing technologies are seen as potentially dangerous or anxiety-provoking. For the purposes of this discussion, we will focus where possible on the more controversial (and more open-ended) realm of enhancement.

Sensory Augmentation

Among transhumanist technologies and research projects, many prominent examples involve the extension or augmentation of human sensory capacity. Platoni [2015], for instance, describes a community of do-it-yourself "body modders" who experiment on themselves by (e.g.) having tiny magnets implanted within their fingers so that they can "feel" magnetic fields. (Note, by the way, that this very simple example illustrates the point that a challenging new technology may in fact be neither digital nor external.) One might imagine variants or extensions of cochlear implants to perform similar mild enhancements of human hearing.

Historically, we can view sensory augmentation technology as a continuation of a venerable process in scientific instrumentation: a telescope, microscope, or Geiger counter might be seen as (external) "sensory enhancements" for humans (cf. the discussion in [Jebari, 2015]). By extension, augmented reality goggles such as the Microsoft Hololens could be seen as part of this tradition. Over time, such tools migrate to positions closer to (or within) the human body itself. Lingley *et al.* [2011] describe, for instance, a wireless contact lens display that was successfully tested on a rabbit. The examples of "magnetic fingers" or enhanced cochlear implants represent early steps toward moving the locus of sensory enhancement to a position within the body itself.

From the standpoint of children's technology, one likely scenario for sensory enhancement would (as suggested by the analogies with telescopes and microscopes) involve endowing students with greater perception for understanding the natural world. We will return to scenarios along these lines in a later section.

Enhancements for Actuation

The flip side of sensory enhancement involves the extension of human muscles or movement. One major line of research along these lines involves extensions to the body (e.g., via robotic limbs or exoskeletons). Again, there is a natural link here to the field of prosthetics (in which replacement limbs are seen as restoring lost function); but some early exoskeleton-like enhancements (e.g., for the construction industry) are already commercialized products.

Exoskeletons alone might be viewed as wearable technology (and hence not quite at the level of full-scale "human enhancement"); but to the extent that such devices might be controlled via brain-machine interfaces, it becomes increasingly hard to disentangle the "external" from the "internal" elements of such artifacts.

One might imagine equipping children with devices geared toward artistic creation (controllable actuators for, e.g., painting or musical performance of a sort unachievable by unaided human muscles); or for manipulating scientific instruments and materials (such as small-scale electronic components, or hazardous chemicals); or in combination with sensors, in devices such as extended robotic fingers to create an enhanced sense of touch.

Brain-Machine Interfaces

Both of the previous subsections have mentioned the subject of direct interaction between electronic or digital devices (such as artificial sensors or robotic exoskeletons) and the brain of the user. By "direct" in this context, the implication is that interaction does not require such intermediaries as keyboards or pedals, but instead is mediated by brain activity through such means as electroencephalographic (EEG) recording. The basic idea is that brain activity can be used to achieve varying degrees of control of computational devices (whether external to the body or not); or the brain itself can be the recipient of signals from external devices (in medical or research settings, this is sometimes managed via direct stimulation of the brain using microelectrodes). For the purposes of this discussion, EEG reading (which is non-invasive) seems to be sufficient to achieve at least some degree of non-muscular control of electronic artifacts (see for example, [Doud *et al.*, 2011]).

Genetic Alteration

While the previous subsections described techniques in which artifacts (such as magnets or actuators) are added to the human body, techniques of genetic alteration change the biology of the human body itself. There are various techniques for making such changes–some speculative–that make the subject difficult to summarize. For the purposes of this discussion, we can focus on existing techniques for somatic gene therapy, in which a genetic change is made in a person but that change does not impact the person's germ line (and therefore is not transferred to descendants). The method of gene alteration is likewise variable, but can be accomplished (as one example) through the injection of a virus containing the desired gene (for a good, brief introductory discussion, see Seedhouse [2014]). Somatic gene alteration has already been used therapeutically to treat disease; again, by analogy with our previous examples, it is plausible (if not always comfortable) to imagine its use to enhance or "improve" human performance. The near-term prospect of widespread "gene doping" in athletic competition is already the focus of discussion (see for example [LePage, 2016]).

There are numerous scenarios in which children might eventually be the focus of genetic enhancement (ignoring for the time being the question of legal restrictions). It might be possible, for example, to alter a child's genetic makeup to improve his or her performance in some particular domain (undersea swimming, playing a musical instrument, dance). Cognitive enhancement via gene alteration (could one improve, say, attention span?) is even more speculative at this point–the genetic components that affect individual cognitive traits are currently not understood at a level that would permit specific improvements. Nonetheless, it seems likely that there will be attempts made to improve human cognition via genetic enhancement within the next quarter-century.

TRANSHUMANISM AND DESIGN FOR CHILDREN

The previous section outlined several of the major lines of work in transhumanist technologies–directions that could plausibly be part of the landscape of "children's technology" in the coming decades. The vast majority of existing discussion of these technologies, however, ignores the specific issues that impact children. In this section we explore several prominent topics that deserve greater discussion, particularly in the area of designing technologies for children.

Developmental issues

Historically, questions surrounding children's use of technology has often centered on the issue of "starting age": should a child really be watching television at the age of three? Should we be introducing children to (say) video games before the age of five? The general arc of the past half-century has been toward greater cultural acceptance of children's use of technology. Where the idea of children programming computers was once seen as startling, computers are now perceived as, if anything, preferentially artifacts of the young–consider the standard media images of the teenage hacker or computer whiz.

In the case of transhumanist technologies, the question of use at an early age is particularly pointed. Consider, for instance, the widespread perception that certain types of skills are best learned early if one wants to achieve a high level of mastery. Children interested in becoming, e.g., top-level violinists, or baseball players, or gymnasts, are often encouraged (or prodded by their parents) to start practicing while young. One might argue, along similar lines, that skill at manipulating a robotic exoskeleton, or at interpreting sensory input from magnetic implants, would be achieved at a superior level if the process started in childhood. Such considerations, if anything, are likely to make children and parents less cautious (and more adventuresome) in experimenting with enhancement technologies.

Indeed, there are some skills (such as language acquisition) for which it is clear that there are biologically typical developmental windows. If one wanted to experiment with (say) sensory enhancement to improve the perception of phonetic patterns in a foreign language, the most successful subjects for such an experiment would likely be children.

Educational issues

Most discussions of transhumanist technology are centered on topics other than education (typical discussions involve improvement in professional performance, enhanced health or longevity, and so forth). This is an odd omission, since there are vivid scenarios in which enhancements for children might be employed in educational settings.

We have already noted that sensory augmentation is particularly suited to certain kinds of scientific exploration (just as the invention of the telescope provided an "enhancement" to human vision for the purpose of studying the heavens). Children might be equipped with enhancements for perceiving polarized light, or high-frequency sounds, or for detecting chemical gradients. While such instrumentation might likely be designed as wearable (rather than implanted, like magnets in one's fingers), the effects might approach those of biological enhancement if the child wears the sensory device continually, or for protracted periods of time. (The historical example of Stratton's "upside-down glasses", in which the user adjusts over a modest time span to glasses that invert the visual image, is telling here. [Stratton, 1896])

Nor need the educational scenarios be drawn exclusively from the natural sciences. We might, for instance, design novel types of devices, approaching the nature of prosthetics, for the purposes of artistic performance–new types of bodily extensions for the purposes of, e.g. playing a string instrument. In fact, it might be that novel artistic forms will be developed in tandem with the enhancement devices needed to attempt them: a musical instrument designed to be used, for instance, by a hand larger and more powerful than the standard human hand.

Ethical issues

Throughout this discussion, a myriad ethical, legal, and policy issues have been lurking in the background. Philosophical debates surrounding the prospects transhumanism are by now hardly new (see Lilley [2013] and Savulescu & Bostrom [2011] for informative discussions), but the question of how these technologies affect children's lives is particularly pointed, and relatively underexplored.

Take, for example, our scenarios of early enhancement of children for the purposes of achieving expertise (say, as a violinist or tennis player). Should a parent be allowed to make a decision in favor of enhancement on behalf of the child? Does it make a difference if the enhancement is electronic (a cochlear implant to make the child more sensitive to the specific timbre of violin music) or genetic (a somatic enhancement to increase the dexterity of one's fingers for playing the violin)? Should parents' rights be limited in this respect?

Naturally such discussion can be broadened to include the child's perspective as well. We are used to cultural policies that limit the decision-making abilities of children (restrictions on voting, for instance). For similar reasons, adult society might wish to place restrictions on a child's ability to opt for a particular enhancement.

Perhaps, let us say, a ten-year-old should not be able to obtain a sensory enhancement because his judgment is not yet to be trusted. What about a seventeen-year-old? The prevalence of risk-taking behaviors among teenagers is well-established (indeed, there are evolutionary arguments to the effect that teenagers *should* be expected to take greater risks than adults). We might soon be faced with a scenario in which numerous teenagers wish to experiment on themselves with enhancement technologies; and this will be accompanied by a need to sort out which technologies are to be allowed, and which forbidden.

The complementary question to "who should be allowed to choose enhancement" is that of accessibility. If *some* people are allowed to choose enhancement technologies, why not all people? Once some prospective young athletes have begun to experiment with altered senses or genomes, shouldn't the same choices be available to all students? There is a related issue of economic accessibility, or equity: suppose a particular enhancement (for, say, playing violin) happens to be expensive to obtain. Is it fair that children from non-wealthy families should be unable to achieve the same level of mastery as children of well-off parents, simply because they cannot afford the same bodily enhancements as their wealthy peers?

One temptation, when faced with the thicket of ethical and philosophical dilemmas surrounding transhumanist technologies, is to attempt to finesse the question by proposing a ban on research and development of all such technologies. Yet there are reasons that it would be unwise to take this course (much like trying to kill the wolf Fenrir outright). For one thing, it might be argued that to forbid such technologies would be to artificially constrain the potential achievements of individuals: perhaps our society would be deprived of scientific understanding or artistic achievement by placing biological limits on what people (and children in particular) can learn and accomplish. Another argument is a pragmatic one: if there are avenues by which people can experiment with enhancements privately or in a do-it-yourself manner, some people will pursue those avenues regardless of legality. Parents might find ways of seeking enhancements for their children despite restrictions; teenagers, being teenagers, might continue to experiment on themselves. In other words, prohibiting enhancement technologies might place societies in the same sorts of scenarios as already exist when prohibiting alcohol (an unsuccessful social experiment in the twentieth-century United States) and certain drugs (a policy with its own associated controversies).

HEURISTICS FOR DESIGN

In the light of the discussion in the previous section, it seems reasonable for this community–the designers interested in children's technology–to propose for debate a number of heuristics, or guidelines, to shape research and experimentation in transhumanist technologies for children. This section is not at all intended as a "manifesto"; it's difficult to approach this topic with any sense of technological or moral certainty. The purpose of the following heuristics, then, is to suggest some starting points for the inevitable design controversies that will emerge over the coming decades.

Heuristic 1: Wearables over implantation. It seems reasonable for the near-term future to give a strong preference to designing technologies that have temporary or easily undone impact instead of longer-term alterations. (This heuristic is familiar to any parent who has argued with their teenage child about the wisdom of getting a tattoo.) In the case of sensory extensions, for example, experimentation with wearable (and removable) devices is a natural preferred option in contrast to bodily implants. The obvious reasoning here would be that since we don't know about the long-term impacts–including behavioral or cognitive impacts–of sensory extensions, it would be sensible to gather as much lore as possible in a setting where extensions can be easily removed or replaced.

Heuristic 2. Craft technologies in preference to large-scale commercial products. The community of "body-modders" described by Platoni [2015] is a sort of "homebrew" group of people experimenting with sensory enhancements on their own, in basements and garages. Undoubtedly there are risks associated with this style of work in contrast to more mainstream, better-funded efforts: the body-modders cannot, for instance, get implants done by medical doctors, so they avail themselves of the services of tattoo artists. Even with these risks understood, however, there are distinct cultural advantages to a style of experimentation that allows, within fairly broad limits, people to create and experiment with their own enhancement technologies in do-it-yourself fashion, rather than pursuing large-scale commercially designed products.

There are several reasons for this heuristic, which is admittedly more likely to be controversial than the previous one. First, in principle it allows a greater openness and transparency about early experimental work: the homebrew communities tend to be open-source and to permit other hobbyists and enthusiasts to pick up and extend their work freely. This avoids the scenario in which corporate researchers are working out of the public eye to avoid imitators; the likelihood in this latter case is that there will be less public discussion of the merits of a particular innovation until it has a large-scale release and is something of a *fait accompli*.

Moreover, there are deeper problems involved, at the cultural level, in responding to large-scale corporate interests in contrast with craft communities. When a product is released it is accompanied by professional advertising to create a perceived need where none might have existed before (cf. [Wu, 2016]); arguably people have more freedom to consider their options in the absence of such professional manipulation. Likewise, when large numbers of people are persuaded to adopt a particular technology, it becomes an increasingly fraught decision on the part of the individual whether to go along or not. (This sort of peer pressure phenomenon–whether it promotes the playing of a particular video game, the acquisition of a tattoo, or the use of a particular fashion accessory–is particularly acute in communities of young people.) Finally, when a corporate product is promoted, other options are regarded as competitors (rather than alternatives) and in some cases are deliberately suppressed.

Heuristic 3: Concentrate attention on children's culture and children's purposes as foundations for innovation. The intent of this final heuristic is to sound what might be an unexpected cautionary note. The caution here is not, in this case, of the physiological risks of transhumanist technologies (though these do exist). Rather, it is to warn against the interpretation of these technologies in terms of the purposes of the adult (and especially the politically or financially powerful adult) community.

The idea here is that there will inevitably be efforts to redefine the constraints of childhood in ways that preferentially highlight the purposes of the designers rather than children themselves. Adults might wish to create innovations that (e.g.) lengthen children's attention span in the classroom; or encourage them to load themselves up with commercial attachments or accessories; or provide products that lead to a loss of privacy (the possibility of a limited sort of "reading the thoughts of another" via brain machine interfaces is often mentioned in discussions of this kind).

We live in a culture that places heavy emphasis on consumption and material acquisition, while simultaneously devaluing alternative themes such as long-term reflection, relaxation, and idiosyncratic interests (particularly those with no discernible monetary reward, such as stargazing). The design community must be aware of these tendencies as it begins to explore the potentially explosive and transformative technologies associated with transhumanism. Every technology, every newly designed artifact for young people inevitably reflects a set of values–what should children be like, how should they spend their time–and these questions will come to the fore with special urgency as we create designs whose impact is increasingly expressed in biological or physiological terms.

SAMPLE RESEARCH PROJECTS

To concretize some of the discussion thus far, this section presents a variety of plausible (if in some cases a bit futuristic) research and design projects involving transhumanist technologies for children. The goal in these examples is to try to keep relatively close to the spirit of the heuristics offered in the previous section.

Project 1. Experiencing animal perception. The term "umwelt" was coined by the German biologist Jakob von Uexküll to denote the concept of "the world as experienced by a particular creature". That is, the umwelt of a bat (which navigates via echolocation) or a dog (whose sense of smell is far more acute than that of a person) is significantly different than that of a human being. One likely project, then, in biology education would be to design sensory enhancements that permit children (or researchers, for that matter) to experience, at least in part, the umwelt of another creature. A set of wearable cat whiskers, or an artificial "dog nose" sensor, or glasses that mimic the compound eye of an insect, could be created as first steps toward this project (again, following the natural heuristic of preferring wearables to more long-term enhancements). By temporarily inhabiting (again, if only in part) the sensory world of an animal, it may be possible to achieve both a deeper intellectual understanding of, and empathy for, the experiences of certain animals.

Project 2. Musical performance via combined hand and brain-machine interface control. Another potential project would be to design novel musical instruments for children that could be controlled by various combinations of physical movements and brain-machine interface control. The degree to which purely neural (as opposed to muscular) control is employed for a given instrument could, in this instance, be a parameter of the design. Each instrument would be played at least in part via input received from EEG signals transmitted from a wearable headpiece.

Arguably this sort of project would resonate with a common element of youth culture involving the playing of an instrument (as suggested by the third heuristic of the previous section). For some children, an especially high level of performance skill might be obtained on an instrument that is, in effect, customized for their own particular mixture of muscular and neural abilities. The result might encourage participation in music for students who otherwise would have been indifferent, or who might be daunted by the prospect of not being the best at some particular traditional instrument.

Project 3. Science education via sensory enhancement. The first project suggestion focused on sensory enhancements as a means toward zoological understanding. One might similarly employ sensory enhancements to (e.g.) directly perceive certain radio wavelengths, or "feel" electric currents, or direct attention to certain color combinations, among many other possibilities. As noted earlier, the history of scientific instrumentation can be viewed as a progressive accumulation of sensory prostheses; a project of this sort could be directed toward creating scientific instruments that are positioned increasingly close to the user's body, and whose use would occur over potentially longer periods of day-to-day activity.

CONCLUSION

The reader familiar with the literature of transhumanism might have already noticed in this discussion certain topics that have been deliberately omitted. In our view, there is no need, at least at present, to speculate on large-scale cosmic-level changes in human consciousness facilitated by transhumanist technologies. We are free, of course, to imagine a coming "singularity" event of human-level artificial intelligence, or futuristic scenarios involving the storage and copying of human connectomes; and indeed it may be that such scenarios, or approximations of them, will come to pass. But the current, plausible frontier of transhumanist technologies–sensory extensions, robotic actuators, brain-machine interfaces, and genetic alteration–gives us plenty to think about, debate, and design in the very near-term future.

In the Norse myth of Fenrir, the wolf was eventually successfully bound: his leash, rather than a ponderous metal chain, was composed of the lightest, most ethereal elements of imagination and fantasy. The myth has a profound, disturbing effect. It suggests that the greatest dangers to civilization are tamed by inventions of the mind, invisible entities that constitute our collective cultural survival. The technologies of transhumanism might steer us toward dangerous cultural territory; but we, as designers, may yet create an intellectual leash that allows the technology to flourish for children in ways that reflect our own abiding and evolving projects and values.

Endnote. An extended, more thorough version of this paper may be found under the "Publications" link at: https://cucraftlab.org Readers wishing to cite this paper are encouraged to access the longer version.

ACKNOWLEDGMENTS

This paper has benefitted, directly and indirectly, from many wonderful conversations over the years. I particularly wish to thank Ann Eisenberg, Gerhard Fischer, Clayton Lewis, Roy Pea, Hal Abelson, Andy diSessa, Ben Shapiro, Gerald Jay Sussman, Uri Wilensky, Andee Rubin, Mark Gross, and the late Edith Ackermann.

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