Sensory Enhancement

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Abstract

Sensory enhancement is a form of human enhancement that aims to extend the sensory capabilities of a person beyond what is possible for a normal human. Sensory enhancement can consist in either an enhancement that improves a sense or that extends that sense to perceive light, sound, tactile stimuli, or chemical traces that are beyond the human range. A sensory enhancement may also add a new sense, such as electroreception or modulate a sense so that it can perform completely new functions, such as echolocation (biosonar). This chapter argues that sensory enhancement could be implemented in mainly two ways: either via the application of digital technology or by genetic engineering of the human body. The potential of augmented reality (AR) and of brain-computer Interface (BCI) technology is also explored in the section on digital

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enhancement. The section on genetic engineering will mainly be concerned with the potential of horizontal gene transfer (HGT). Three arguments on the normative aspects of sensory enhancement are also presented in this chapter. The first considers the instrumental value of being able to perceive new forms of artistic expression. The second concerns the idea of diversity and whether sensory enhancement could increase human diversity. The third argument departs from the "capabilities approach," formulated by Amartya Sen and Martha Nussbaum, and sketches out the position that we may be deprived in comparison to some possible future enhanced people, even if we do not regret being so.

Introduction

Sensory enhancement is in this context an instance of *human enhancement*. Thus, a correction of deficient hearing or sight is not covered here. At the moment, glasses and cochlea implants are not sensory enhancement technologies. Should telescopes and microscopes be defined as sensory enhancement technologies? Here the distinction is more tenuous and based on what we perceive to be part of a person's abilities. For something to count as an enhancement, this must add or extend a person's functioning, or ability to do something. Clearly we do not believe that a person who owns a telescope has the ability to see the Galilean moons, even if that person is in some more general sense able to do it. Human enhancement technologies ought to therefore be seen as artifacts that are to a certain degree integrated with our persona. According to a narrow view, only things that are physically integrated, i.e., attached or assimilated to the body, ought to count. A clear example of this would be a vaccine. On a more inclusive view, devices that form part of a person's mental self-representation should also be included. On this view, if a person perceives glasses, clothes, contact lenses, and (perhaps) a smartphone to be part of his or her body, these devices count as human enhancements. This vague characterization will vary in different contexts and across generations, but it will suffice for the purposes of this discussion. Another distinction that ought to be considered is between a sensory enhancement that allows us to perceive a sensory input without giving us a new sensory quality and an enhancement that would literally change how we see the world. For example, a thermographic camera forms an image of infrared light using visible light. An observer can therefore indirectly see infrared light. This sensory experience probably differs from what it might be like to be able to perceive infrared directly, which of course may differ radically between different individuals and species. However, an indirect experience of the world may be just as useful for practical purposes as a direct one. We should therefore include technologies that allow people to "see" indirectly in our definition of sensory enhancement. Another relevant distinction is between enhancement of our *sensory capacities* and the enhancement of our *perception*. Whereas the first changes *what* we perceive, the second changes *how* we perceive. As an example of perceptual enhancement, consider some drugs that allegedly enhance the way we perceive music, and allow us to distinguish between subtle nuances. The difference here is that whereas sensory enhancement is primarily informational, perceptual enhancement is primarily phenomenological. This chapter will not be concerned with perceptual enhancement.

Some of the proposals that have been made for human enhancement refer to new and improved sensory functions. For example, concrete research is currently being performed on a bionic contact lens the display of which will be superimposed on what one sees naturally. Other proposals include improved vision (ultraviolet and/or infrared wavelengths), more acute hearing, and chemical sensors. Although such possibilities have been mentioned in the literature on enhancement, sensory enhancement is not the main topic of a single publication that is tracked in the philosophical database *phil papers* or the medical database *pub med*. This chapter will argue that this lack of attention is regrettable, due to the potential importance of sensory enhancement. It will isolate the issue of sensory enhancement from the more general issue of enhancement, covering both the more speculative and the more realistic possibilities for enhancement, but with a clear emphasis on the latter.

Outline of the Opportunity Space

Any plausible account of future developments demarcates the possible and interesting from the purely fantastical. This is no trivial task. Yet, any discussion of this nature requires that we anchor our expectations along some space of possible outcomes. I suggest a possible heuristic for doing this in the context of sensory enhancement. Although physics sets a definitive boundary from what we can expect to be possible, the boundary set by biology is narrower and more interesting. More specifically, I propose that when thinking about the possibility space of potential sensory enhancements, we confine ourselves by the boundary set by animals in the phylum *chordate* (vertebrates). While the species diversity within this phylum is formidable, ranging from fish and bird to mammals, these animals share a relatively well-developed brain, complex sensory organs, and a circulatory system with a heart (Romer and Parsons 1986). According to the proposed "chordate-heuristic," a biological function in the realm of sensory perception that is possible in this phylum might be possible for humans in the future, given the appropriate technology.

In this chapter, two technology trends are extrapolated to provide a plausible basis for these considerations: the rapidly advancing prowess of genetic engineering, in particular horizontal gene transfer, or HGT. This technology consists in the transfer of genes between organisms. The second technology trend is the miniaturization and price reduction of processing power and the probable future ubiquity of computers and sensors. Two technologies are of particular interest here. First, augmented reality, or AR, is computer-generated sensory input that is superimposed on reality. This makes mediation of sensory inputs possible.

The second technology is brain-computer interface, or BCI, which refers to a device that allows direct communication between the central nervous system and a computer by means of electrodes. Such devices are already used in cochlea implants and artificial retinas.

Digital Senses: From Augmented Reality to Brain-Computer Interface

Augmented Reality

As computers and digital sensors have become smaller, cheaper, and more powerful, their usefulness for enhancement purposes has become evident. It is reasonable to conjecture that any sensory data gathered by a machine that is either wearable or possible to connect to the internet could, with the appropriate interface, add to our own sensory experience. Increased digitalization has made sensory-enhancing technology cheaper and better. Night goggles are, for example, widely used by military forces and police officers all over the world. As these goggles and other similar technology increasingly rely on computers, we can reasonably expect that night vision might become cheaper and more suited for nonprofessional use. Digital hearing aids can enhance audition both by amplifying sounds and enhance signal to noise ratios in the environment. However, much more radical enhancement can be achieved by "outsourcing" our perceptual apparatus with the help of emerging technology. Consider the field of augmented reality or AR. Augmented reality is a live, direct or indirect, view of a physical, real-world environment whose elements are augmented by computer-generated sensory input such as sound, video, graphics, or GPS data. A head-mounted display (HMD) places images of both the physical world and registered virtual graphical objects over the user's view of the world. Project Glass is a research and development program by Google to develop an augmented reality head-mounted display (HMD). This product will, according to Google, be available in the consumer market in 2014 (Goldman 2012).

Bionic contact lenses are being developed to provide a virtual display that could have a variety of uses from assisting the visually impaired, to the video game industry. These devices will have the form of conventional contact lenses with added bionics technology. These lenses will eventually have functional electronic circuits and infrared lights to create a virtual display (Collier 2010). Leading researchers in this field state that "Looking through a completed lens, you would see what the display is generating superimposed on the world outside" (Hickey 2008). In 2011, Lingley et al. created and tested in vivo a functioning wirelessly powered prototype with a single-pixel display. These contact lenses were tested on rabbits and showed no adverse effects (Lingley et al. 2011).

The potential to enhance vision and hearing with the help of AR is quite significant. A likely development in the near future is what is sometimes referred to as "the internet of things" (Ashton 2009). The idea behind this concept is that ordinary things will increasingly be equipped with identification tags, computers, and sensors that feed their information through the web. Thermal imaging cameras are already widely used as tools for surveillance, and are becoming so cheap that they are available as consumer products. Increasingly, these cameras are equipped with connectivity, allowing users to tap into them via Smartphone apps. Night vision cameras and other electronic equipment with sensors capable of obtaining sensory input beyond the human ability could easily be mounted on cars, streetlamps, and signposts and thus provide wireless information to AR systems, thereby providing users with night vision, vision in the UV-range, telescopic vision, and other kinds of enhancements. The ability to accurately measure distance, size, and determine the mass, density, and the trajectory of an object are typical examples of enhancements that are well suited to an AR system. Hearing could just as plausibly be outsourced to sensors embedded in the environment. Sensors could pick up ultra- and infrasound, enhance accuracy, and add information about the source of the sound.

Electric noses are devices that can effectively detect small concentration of chemicals in confined spaces. With direct applications in security, medicine, food production, and chemical safety, this technology has a clear commercial potential. With an appropriate interface, such as either AR or a brain-computer interface, this technology could be used to enhance our sense of smell. Like connecting an artificial limb with the somatosensory system, or directly stimulating ocular nerves to repair sight, olfactory enhancement has the potential to profoundly affect functioning. Whether or not these electric noses will enter the consumer market for enhancement purposes remains to be seen (Wilson and Baietto 2009).

Magnetoreception is a sense which allows an animal to detect a magnetic field to perceive direction, altitude, or location. It has been hypothesized that the ability to sense the Earth's magnetic field is essential to some birds' ability to navigate during migration (Walcott 1996). Magnetoreception in humans has been achieved by magnetic implants used as non-permanently attached artificial sensory "organs" (Nagel et al. 2005). Small neodymium magnets can be placed under the skin (usually the fingertips) so that the movement of the implant in the presence of magnetic fields can be felt by the individual. These implants can in this way be used to convert nonhuman sensory information into touch (Hameed et al. 2010). As with AR, this kind of enhancement does not provide the user with a new sense directly. Rather it allows a user to gather new information but via the user's sense of touch. These implants are to some extent used by subcultures that experiment with body modification (Norton 2006).

Brain-Computer Interface and Sensory Enhancement

Since AR superimposes sensory data in way that we can interpret, it only gives us a "superficial" enhancement. For example, a device that can allow a user to "see" UV light will represent this light through the user's AR device into light that the user is able to perceive. Although this might be interesting and useful, it does not fundamentally alter our perceptual apparatus. However, brain-computer interface (BCI) based devices could do just that. A BCI connects the central nervous system directly to a computer, and allows information to be transferred between these two systems through electrical impulses. Cochlear implants are prosthetic devices that use this technology and that feed sensory information directly to the auditory nerve. BCI implants could in theory mediate sensory input without adapting it to the range of the human ear or eye. Thus, a BCI-mediated sensory experience would probably differ from that mediated via AR. Whereas we are likely to see AR enhancements of the kind discussed above in a few years, BCI enhancements require several scientific breakthroughs regarding both miniaturization and the understanding of the relevant mechanisms in the brain. In addition, since a BCI that provides this amount of information to specific parts of the brain requires an invasive procedure, we are not likely to see this kind of enhancement to be widely adopted unless a noninvasive (transcranial) method to accurately target parts in the brain associated with perception is devised. Although a novel interest for noninvasive electrical stimulation has had a kind of renaissance, neither of the two main technologies, i.e., transcranial direct-current stimulation and transcranial magnetic stimulation, have yet been used to produce sensory experiences similar to those of a cochlea implant.

Gene Transfer

Horizontal gene transfer (HGT) consists of the transfer of genetic material between organisms. Since genes are in sense instructions to produce proteins, new genes imply new proteins and thus new abilities. For example, this is the technique behind GloFish, a zebra fish with genes that encodes the green florescent protein, originally extracted from jellyfish (Zhiyuan et al. 2010). HGT experiments in animals have so far failed to produce results that would justify performing gene transfer in humans; however, gene transfer techniques may eventually be used for enhancement purposes. While any existing animal sensory modality suggests a possibility for future enhancement, visual enhancements are of particular interest (Jacobs et al. 2007). An inherent plasticity in the mammalian visual system may permit the emergence of a new dimension of sensory experience based solely on gene-driven changes in receptor organization. However, it should be noted that sensory systems are in large part integrated in the central nervous system. We should not expect to get a bird's vision by simply implanting genes that alter the form of the eyes. To benefit from bird's visual systems, we also need some of the neurological hardware that birds have and that we lack. This kind of gene transfer is therefore much more complicated and advanced than that which allows the zebra fish to glow. Keeping that in mind, I will now explore some possible sensory modalities that could be of interest for researchers to consider.

Although human vision is quite good when compared with that of other mammals, the visual systems that some birds enjoy are simply formidable. There are two sorts of light receptors in the bird's eye, rods and cones. Rods, which contain the visual pigment rhodopsin, are better for night vision, because they are sensitive to small quantities of light. Cones detect specific colors (or wavelengths) of light, so they are more important to color-orientated animals such as birds. Most birds are tetrachromatic, i.e., in possession of four types of cone cells, each with a distinctive maximal absorption peak. In some birds, the maximal absorption peak of the cone cell responsible for the shortest wavelength extends to the ultraviolet (UV) range, making them UV-sensitive. Birds can also resolve rapid movements better than humans, for whom flickering at a rate greater than 50 Hz appears as continuous movement. This means that while humans cannot distinguish individual flashes of a fluorescent light bulb oscillating at 60 Hz, birds like budgerigars and chickens have flicker thresholds of more than 100 Hz. Birds can also detect slow moving objects. The movement of the sun and the constellations across the sky is imperceptible to humans, but detected by birds. The ability to detect these movements allows some migrating birds to properly orientate themselves (Jones et al. 2007).

Many animals have better night vision than humans, the result of one or more differences in the morphology and anatomy of their eyes. These include having a larger eyeball, a larger lens, a larger optical aperture (the pupils may expand to the physical limit of the eyelids), and more rods than cones (or rods exclusively) in the retina. Among other animals, cats and dogs have a layer of tissue in the eye that reflects visible light back through the retina. This tissue, referred to as “tapetum lucidum,” increases the light available to the photoreceptors, allowing the animal to see in poor light conditions.

Some animals have been known to perceive infrasonic waves going through the earth caused by natural disasters and can use these as an early warning. Infrasound is also used for long-distance communication by many of the large mammals. For example, elephants produce infrasound waves that travel through solid ground and are sensed by other herds using their feet, although they may be separated by hundreds of kilometers (Payne et al. 1986). These calls range from 15 to 35 Hz and can be as loud as 117 dB (Langbauer et al. 1991). Other animals are able to perceive ultrasound. For example, bats can detect frequencies beyond 100 kHz, possibly up to 200 kHz (Popper and Fay 1995).

Echolocation is a biological sonar used by bats, dolphins, and other animals. They use echolocation by emitting sounds out to the environment and listening to the echoes that return from the various objects. The animal can measure the range to the objects surrounding it by measuring the time delay between the animal’s call and the echo. The relative intensity of the sound and the difference in time delay between the animal’s ears gives the animal an idea of the horizontal angle of the object. Echolocation requires, in addition to the ability to emit sounds at high frequencies, also the ability to construct a detailed representation of a complex environment from sound. Thus, although echolocation does not require new sensory modalities, it requires neuronal structures alien to the human brain (Jones 2005).

Electroreception is the ability in some animals to sense electrical stimuli. It has been only been observed in aquatic or amphibious animals, since water is a much better conductor than air. Electroreception is used in electrolocation (detecting objects) and for electrocommunication. Passive electroreception relies upon ampullary receptors which are sensitive to low (below 50 Hz) frequency stimuli (Collin and Whitehead 2004).

While these sensory modalities might prove very difficult to transfer to a human organism, the mere fact that they are possible in species that are relatively similar to us suggests that it is possible. We should also distinguish these *biologically* possible sensory modalities with other, merely *physical* possibilities. While it might be consistent with the laws of physics to be able to perceive neutrinos, this is not likely to happen for any organism that is even remotely human. In comparison, the biological changes for some of these sensory modalities are quite modest.

Should We Accept Sensory Enhancement?

Although human enhancement has been part of the bioethics debate for more than a decade, the issue of sensory enhancement has garnered little attention. A possible explanation may be that sensory enhancement seems to yield small benefits in contrast with, for example, cognitive enhancement. The claim that the benefits of sensory enhancement will at best be modest seems plausible. However, some justification for this kind of human enhancement is still possible to formulate. In this final section, this chapter will sketch out three arguments in favor of sensory enhancement, all of which need to be explored further.

Instrumental Value: To Perceive New Value Structures

The English expression “Art for art’s sake” expresses the idea that art has intrinsic value, separate from whatever utility it may provide. This view is often defended by philosophers who ascribe to pluralist notions of intrinsic value, such as William Frankena and others (Frankena 1973). Some forms of artistic expression such as music, photography, and cuisine are directed to one or more specific sensory modalities such that these senses are necessary to experience the aesthetic beauty or excellence conveyed by these expressions. Sensory modalities are thus instrumental for us to be able to perceive or experience these sources of value. If some sensory enhancements became widespread, art that would require these enhancements to be perceived might be produced. Ultrasound musical instrument is one possible example. Although some sensory modalities are of little practical benefit, such as the ability to perceive UV light, these enhancements may be instrumental for us to experience and express new forms of human creativity. Although the deaf community can plausibly make the case that being unable to hear does not imply that one’s life contains less welfare than otherwise, they cannot deny that being deaf deprives the person from experiencing a certain form of human expression that is, if not intrinsically valuable, at least very enjoyable (Cooper 2007). Music as such is not the only possible form of expression, and we may all be "deaf" with respect to the as of yet unexplored and unimagined forms of cultural activity that may involve nonhuman sensory modalities. The argument against deafness can thus be deployed in favor of extending the range of human sensory modalities. It is worth noting that this argument is not specific to sensory enhancement. For example, some forms of cognitive enhancement may allow us to appreciate some literary works or the aesthetic qualities in abstract mathematics.

However, it is not obvious that the analogy between music and a hitherto unknown but possible source of intrinsic value can be made. Whether this analogy is adequate depends on the source of value of music and other existing art forms. Does the value of art rest on the communitarian importance of participating and sharing an experience across time and cultures? Or does the value of art depend on its intrinsic aesthetic qualities? An art form based on nonhuman sensory modalities would not in the same sense carry these communitarian values. However, some art theoreticians argue that art has cognitive value, in virtue of its capacity to increase our understanding on some topic (Schellekens 2007). Furthermore, these hypothetical nonhuman art forms may be just as beautiful and aesthetically pleasing as existing art forms. A similar argument in favor of expanding sensory modality has been formulated by Nick Bostrom. He argues that although our human limitations are so pervasive that we fail to notice them, there is likely to be a huge range of modes of being in and perceiving the world that allow us to engage in very valuable activities. It is therefore important to explore these possible modes of being (Bostrom 2003).

Two Arguments from Diversity

The human species is extraordinarily homogenous in comparison with other primate species, which often include a number of subspecies. It has been hypothesized that this relative homogeneity may be due to a great disaster in our recent evolutionary history (Ambrose 1998). This homogeneity may prove problematic. Diverse societies are more innovative and more adept to understand disruptive social or natural dynamics (Kandler and Laland 2009). Homogenization may expose us to risks if our limited frames of reference reduce our ability to understand and imagine possibilities and risks. Remember that for many unexpected catastrophic events, it is our failure to anticipate these events that make them so dangerous (Taleb 2007). By increasing diversity among the constituent members of our global civilization, we may increase the possibility to imagine and anticipate some of the risks that we have as of yet failed to conceive of. Sadly, the modern condition seems to reduce the diversity of opinions, values, and beliefs. Urbanization, globalization, and a truly global commercial culture have already led to the elimination of many languages and cultures (Abrams and Strogatz 2003). As mankind will become predominantly a species of city dwellers in the twenty-first century, this process will probably accelerate. As sensory modalities constitute literally a new perspective on the world, the proliferation of different combinations of perceptual apparatuses may contribute to a significant degree to different ways of relating to and interfacing with the world. As has been discussed in this chapter, many of the sensory modalities that may become possible include trade-offs. There is no "perfect sense," or perfect combination of enhancements that would be great for anyone in any context. For example, night vision may make a person react aversely to strong light or rapid changes in light conditions. Accurate hearing may sound great, but may cause stress and anxiety in loud environments. It is therefore unlikely that everyone will opt to implement the same enhancements.

Is there an intrinsic value in diversity? Some philosophers and bioethicists tend to believe so, and this author is inclined to share that appreciation. Certainly, many opponents of human enhancement fear that human enhancement may bring about the homogenization of the human species (Kass 2002). These authors seem to ascribe intrinsic value to the prevailing level of diversity. However, it is worth reflecting on whether or not mankind happens to find itself at an optimal (from both an intrinsic and instrumental perspective) level of diversity. As this seems unlikely, the intuition that we happen to be at a local optimum with regard to diversity may reflect a status-quo bias, as argued by Nick Bostrom and Toby Ord (Bostrom and Ord 2006). Perhaps *increased* diversity is morally desirable. Sensory enhancement could bring about this diversity.

The Intrinsic Value of Sense Modalities

Amartya Sen and Martha Nussbaum formulated in the 1980s a view of human welfare that has become influential in welfare economics, referred to as the capabilities approach (Sen 1989). According to this view, human welfare is not possible to reduce to subjective well-being, but neither can it be plausibly measured in resources (Sen 1993). Rather, it is what we can accomplish with these resources that matters. According to the capabilities approach, there are some functional capabilities that are good for the person who has them, and people deprived from these capabilities are worse off even when the deprived person does not want or cannot imagine having these capabilities. Imagine, for example, a slave working in a mud brick factory. This person may believe that it would be bad for him or her to be able to read. This does not make the slave less deprived, according to the defendants of this view (Nussbaum 2000). Functioning includes bodily health, bodily integrity, and being able to use one's senses and so on (Sen 1993). Could this framework be extended to include human enhancement? Although this is not what the proponents of the capabilities approach intended, the definition of "normal" health, perceptual ability, and limb functionality seems to be highly context-sensitive. In modern welfare-states, it is a sign of deprivation to lack teeth in one's late fifties, something that was normal 100 years ago. Are we in a similar sense deprived because we lack the sensory modalities that might be available to future generations? If the capabilities approach is correct, the mere fact that we do not regret lacking night vision does not imply that we are not deprived.

Conclusion

Sensory enhancement has long been neglected in the debate on human enhancement. This chapter has argued that sensory enhancement matters and that there are reasons to allow people to experiment with it. Since the technological feasibility of some sensory enhancements is quite tangible, and that the first sensory enhancement devices may reach the mass market in only a few years, there is an evident need for a discussion on the normative issues involved.

Cross-References

- ▶ Ethical Implications of Brain–Computer Interfacing
- ▶ Ethical Implications of Cell and Gene Therapy
- ▶ Ethical Implications of Sensory Prostheses
- ▶ Ethical Issues in Cochlear Implantation
- ▶ Ethics of Brain–Computer Interfaces for Enhancement Purposes
- ▶ Gene Therapy and the Brain
- ▶ Reflections on Neuroenhancement
- ▶ Research in Neuroenhancement

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