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Technology and the Body: the (Im)Possibilities of Re-embodiment

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Abstract This article argues for a more rigorous distinction between body extensions on the one hand and incorporation of non-bodily objects into the body on the other hand. Real re-embodiment would be a matter of taking things (most often technologies) into the body, i.e. of incorporation of non-bodily items into the body. This, however, is a difficult process often limited by a number of conditions of possibility that are absent in the case of 'mere' body extensions. Three categories are discussed: limb extensions/prostheses, perceptual extensions/prostheses and cognitive extensions/prostheses. For each category, a distinction between extensions and incorporations is proposed, and the conditions of possibility for real incorporation are discussed. These conditions of possibility differ in each category, but in general they ask for radical or fundamental alterations not only in the motor and/or sensory or cognitive constitution of a human subject, but also in his or her subjective experience.

Keywords Bodily extension · Cognitive extension · Prostheses · Re-embodiment

For me to be a utopia, it is enough that I be a body.
Michel Foucault, *Utopian Body*, 1966[1]

[1] *Le corps utopique (Utopian Body)* is the title of a 1966 radio broadcast, published in 2004 by the Institut National d'Audiovisuel, Paris. It has never been published as a text until the English translation by Lucia Allais, pp. 229–234, in *Sensorium, Embodied experience, technology, and contemporary art* (ed. C.A. Jones), Cambridge: MIT Press, 2006.

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1 Introduction: Technology and the Body

Humans are experts when it comes to acting in a world infused with technology. Yet, we are no natural-born experts when it comes to faithfully describing and analyzing our *experience* of acting in a technological world, nor is it easy to discern the conditions of possibility for our experience with technologies. Phenomenological-philosophical descriptions of acting with technologies and cognitive-scientific analyses of it, can nevertheless clarify, up to a certain degree, the experience of technology and its conditions of possibility. In contrast to the idea that the use of technology implies the ability for *dis*embodiment, or a neglect of the body, I want to prepare the ground for the opposite claim, namely that this experience requires the capacity for *re*-embodiment, not for disembodiment. In order to do so, we have to examine the various domains and ranges in which the subject is capable of re-embodying itself.

I will first give a tentative classification of domains in which re-embodiment is at stake, in order to then pose a number of questions. Finally, I will propose for each domain some directions for answers. The overview pertains to three categories in which the possibilities and impossibilities of re-embodiment are discussed: limb prostheses, perceptual prostheses and cognitive prostheses.

The cyborg-years that lie behind us or that we are still living in, have fetishized the prosthesis, and have fed people's minds with both unwarranted utopian hopes and dystopian fears, but also with a fundamentally flawed view on humans' bodily, sensory/perceptual and cognitive constitution. Popular culture has provided us with thrilling films like *Robocop*, *The Terminator,* or *The Lawnmower Man* in which the use of prostheses and bodily extensions is effortless, where cyborgs are omnipotent, and in which we can upload ourselves into VR. In general, but on grounds that are different, I share the critical attitude toward the prosthetic of, e.g., Ihde and Sobchack. Ihde, in his (2002) is critical of all the technofantasies in popular culture, and shows how technological interventions often remain trade-offs and compromises, that fall short of the bionic technofantasies à la *Robocop*, *Bionic Man* or *Terminator*. According to Sobchack (2004), herself an experienced prosthesis-user, the prosthetic functions largely as a metaphor of which the literal and material ground is forgotten or even disavowed. Moreover, 'prosthetic' metaphors often are reductive rather than expansive. Similarly, many authors use the prosthetic as a rather general premise, such that all kinds of equipment (cars, typewriters, hearing aids, silicon implants, glasses) are considered as prostheses (cf. Jain 1999). However, there is little reason to think that all these instances of 'prostheses' are equivalent. In the present contribution, I would like to get back to the prosthetic realities themselves. My sources for doing so are threefold: phenomenology, cognitive science, and, also, contemporary art. The reason for including the latter is the often lucid way in which the arts explore or criticize new technologies and their concomitant fantasies. VR, for example, is a place where contemporary art and cyborg-fantasies meet and I shall discuss some examples.

2 Categories of Bodily 'Technologization': Limb, Perceptual and Cognitive Extensions and Prostheses

The main question that I will try to answer is to what extent we can 'technologize' our bodies. This question is not new, and has been posed repeatedly by many others. Ihde, Sobchack, Haraway, and Clark—to name just a few well-known examples from the philosophical forum—all have commented extensively and sometimes critically on the possibility of extending human bodies and human capacities. Popular questions include the question if

we can be or become cyborgs, and if so, to what extent. Have we, or could and should we, become 'posthuman'? The scope of the discussion on the 'technologization' of the human body and the embodied subject is very broad and inevitably multidisciplinary. Therefore, and in order to make the above questions some more tractable, I'd like to tentatively distinguish the following domains of 'technologization' of the embodied subject. The reasons for differentiating between 'prosthesis' and 'extension' will be explained further.

(1) Technologies that primarily aim at altering our *motor* capacities, called limb prostheses or limb extensions.
(2) Technologies that primarily aim at altering our *sensory* capacities, called perceptual prostheses or perceptual extensions.
(3) Technologies that primarily aim at altering our *cognitive* capacities, called cognitive prostheses or cognitive extensions.

The differentiation between these three kinds of prostheses/extensions is not absolute or radical. That means that many, if not all, prostheses and extensions do not alter only one bodily dimension, but many. A primarily motor prosthesis, such as a replacement leg or part thereof, will not only alter the motor dimensions of the body, but also the way the subject experiences the world. A sensory extension such as the blind man's cane is meant to alter perceptual experience, but is heavily motor based. In general, motor behavior and perception/experience cannot be decoupled (cf. the sensorimotor account of perception, O'Regan and Noë 2001).

The third category is not a straightforwardly bodily category in the sense that a strictly bodily capacity would be altered. Yet, it certainly is a 'technologization' of the embodied subject and cognitive prostheses/extensions figure prominently in discussions about posthumanism and cyborgization. I hope that along the way it will become clearer why these differentiations, which do not pertain to essences but rather to priorities, make sense.

I should also mention a fourth possible category, namely internal prostheses. Internal prostheses are technologies that are literally taken into or inside the body. This category splits into two subcategories. A first subcategory consists of internal prostheses that have a direct impact on our in-depth body (for an account of the in-depth body, Leder 1998, 1999; De Preester 2007b), and that do not directly or primarily aim at altering our sensori-motor body (e.g. cardiac stents, pacemakers, or valves, or substitution parts for arteries, but also organ transplants). A second subcategory consists of prostheses that do alter the motor body, but that remain internal (e.g. hip, ankle, elbow or knee replacements). I will not treat internal prostheses because the problems and questions pertaining to them are in important respects different from those that have to be met here. The first reason for not including them in the following discussion, is that internal prostheses give less rise to the confusion over the distinction—central here—between body extensions on the one hand and prostheses on the other hand. The second reason is that internal prostheses are not a matter of *embodiment relations*. Embodiment relations are relations that involve experienced uses of technologies which remain detachable, and are in use quasi-transparent (Ihde 1979, 1990, 2008). Internal prostheses most often are not detachable (at least not without life-threatening consequences), and they often do not have the characteristic of semi-transparency. A third reason is the difference between the (possible) degree of awareness of internal prostheses and the way external prostheses are experienced. Awareness of internal prostheses often is more indirect, whereas external prostheses can be experienced in a much more direct way. Ihde nicely illustrates the experiential indirectness of internal prostheses with the example of his own cardiac stent: "Interestingly, I have no direct bodily awareness of the stent at all—unlike my tooth crowns,

it remains totally 'invisible' although the indirect awareness of energy levels may be noted" (Ihde 2008: 38).[2]

Let us start with the first category: technologies that primarily aim at altering our motor capacities. We can think here of ordinary tools, but also of replacement technologies for missing limbs or parts thereof. Since tools that alter our motor capacities most often are manipulated or wielded by the limbs (or hand and feet, the extremities of the limbs), the name limb extensions and limb prostheses seems appropriate.

3 Limb Extensions and Limb Prostheses

3.1 Extending Our Limbs with Tools

We know from experience that in successful tool use, a tool becomes quasi-transparent. Tool-use seems to point to the extensible nature of human embodiment. The knife and fork I use at dinner, the bike I am riding, the pen I'm writing with, the hammer I use for nailing—in successful tool use, we are closer to what we are dealing with than to the tools and instruments we use to that end (Heidegger 1962; De Preester, to appear). More ambitious extensions can be found in cases of telemanipulation. A nice example comes from the domain of fine arts.[3] In Ken Goldberg and Joseph Santarromana's *Telegarden* (on-line in 1995) a web of surfers uses a computer in order to move a robot arm in a 'garden'. This garden is just a plot of soil, but the robotic arm can be controlled over the internet and the users can plant seeds, water plants and view specific areas of the garden. The user of the arm can be objectively far removed from the spot where the garden is, and, moreover, he or she is mediated to the garden and to the arm itself via a pc and the internet, but this does not preclude a feeling of bodily extension (cf. also De Preester 2007a). This means that what mediates us to the world acquires itself a certain degree of transparency. A number of cognitive-scientific studies suggest what the processes underlying the transparency of the instruments that extend our limbs might be.

A study on tool use by monkeys (Maravita and Iriki 2004) reports that bimodal neurons, i.e. neurons responding both to visual and tactile stimuli, respond before tool use to visual stimuli *near* the hand. During tool use, however, these neurons start to respond also to stimuli at the far end *of the tool*. Thus, tool use results in a stronger integration of visual stimuli at the far end of the tool and tactile information at the hand wielding the tool. If the monkey retrieves food with the hand, the visual receptive fields of the neurons responding to somato-sensory and visual stimuli arising from the hands, are limited to the hand. But if the retrieval is done with a rake, visual receptive fields expand and include both hand and tool. Crossmodal interference between tactile and visual stimuli during tool use suggests a similar underlying process in monkeys and in humans (Maravita et al. 2002).

Thus, we know that during tool use body-part-centered visual receptive fields are activated when objects approach the tool, and not only the hand itself. "From this finding, we would predict that tools are represented as belonging to the bodily self. However, although this may be true in some weak sense, the feeling of ownership we have for our bodies clearly does not extend to, for example, the fork we use at dinner" (Botvinick 2004: 783). If we get off our bike, we do not experience a loss of feeling of bodily ownership over the bike.

[2] Cf. also Jean-Luc Nancy's experiences after a heart transplant in his book *L'Intrus (The Intruder)*, Paris: Galilée (2000).

[3] For an account of how the body explicitly surfaces in contemporary fine arts and performance arts, see De Preester (2007a).

Therefore, the two aspects of successful tool use are the quasi-transparency of the tool and the extensible nature of human embodiment. The above account of visuotactile neurons can give an explanation of why a tool becomes quasi-transparent. The neurons that respond both to somatosensory information from a particular body part and to visual information from the space adjacent to that body part, play an important role. For some such bimodal neurons, the visual receptive field remains anchored to the body part when this part is moved in space. This is important for coding action space in coordinates that are body-centered. When we use tools, our physical body structure is extended and, consequently, our action space is enlarged. The crucial point is that "[…] in some of these bimodal neurons the vRFs [visual receptive fields] expanded to include the entire length of the tool, after the monkey had performed five minutes of food retrieval with the handheld rake" (Maravita and Iriki 2004: 79–80). Without further speculating that these vRF expansions constitute the neural substrate of assimilation of the tool into the 'body schema' (cf. Maravita and Iriki 2004), the suggestion that the tool becomes quasi-transparent because of strong correlations between the visual and the somatosensory is rather powerful. It is as if the tool withdraws into the sensorium of the body, or rather, as if the tool extends not only the motor body, but also the sensorium of the body. This results into a feeling of quasi-transparency in which the tool co-enables our experience but is itself not in the focus of our experience. The quasi-transparency of the tool is related to a feeling of *non*-mediation, caused by the altered correlation between somatosensory and visual information.

In spite of the above results, a general confusion remains both in cognitive science and in philosophy about whether tools are 'incorporated' into the body, or whether they 'extend' our body. In fact, Merleau-Ponty's (1945) very inspiring but also confusing phrasing remains to be clarified. In discussing the blind man's use of a cane,[4] Merleau-Ponty says that the cane becomes 'incorporated' (Merleau-Ponty 2002: 139) into the man's body image (ibid: 141), but he also says that the cane becomes "a bodily auxiliary, an extension of the bodily synthesis" (ibid: 153). In what follows, I briefly present a recent possible clarification of the distinction between body part and bodily extension, or between incorporation into the body and extension of the body.

3.2 Replacing Missing Body-Parts

Tools may extend the body, but it might be less adequate to say that a tool really becomes part of the body, or that it is really incorporated. In the previous section, it is suggested that tool use does not involve changes in the feeling of ownership over one's body. Tool use induces changes in motor and sensory capacities, but not in body ownership. True incorporation, in contrast, involves changes in the feeling of body ownership itself. The use of limb prostheses may shed more light on this matter. Especially in theoretical and speculative texts, a prosthesis is considered as follows. "For instance, Scarry reports that the medical community working with prosthesis users often talk of the need to transform the prosthetic limb from an 'inert supplement' or an 'extracorporeal structure' into a corporeal one. Similarly, a number of researchers have proposed that an artificial limb may become 'part of' the user" (Murray 2004: 964). Thus, ideally, a prosthesis is not an inert supplement to the body, but neither is

[4] The use of a cane by the blind primarily aims at altering or restoring a perceptual capacity, not a motor capacity, and therefore rather belongs to the second category. Because of its peculiar nature, namely a physical extension of the arm and hand, the way in which it withdraws strongly resembles the way limb extensions withdraw into the sensorium of the body. Here, somatosensory information cannot be correlated with visual information, but it can be integrated with auditory information (cf. Làdavas and Serino 2008).

it a mere tool. Something more seems to be desired in order to speak of a successful limb prosthesis, i.e. that it becomes a *part of* the body.

One condition for being a part of the body, is that the prosthesis becomes a *knowing* body part, in other words, something that is no longer a mere object attached to the body, but something that withdraws into the sensorimotor apparatus of the body. The following quote, from a male with congenital absence of the foot, precisely describes the experience of being percipient at the boundaries of the prosthesis, and he also points to the transparency of his prosthesis. "One of the major factors in my satisfaction with a new prosthesis is how little I feel it. That may sound strange, but to me, my prosthesis is an extension of my body. (I can actually 'feel' some things that come into contact with it, without having to see them […]). It must 'feel' as close to not being there as possible" (Murray 2004: 970). The question is, however, if the characteristic of not-being-there can be responsible for the feeling of incorporation. A tool can also feel close to not being there: in successful tool use, the tool is 'ready-to-hand', quasi-transparent. Therefore, since tool use shares this characteristic of withdrawal into the sensorimotor body, the distinction between tool and prosthesis cannot be made on the basis of this characteristic. Notice also, that this person is not talking about incorporation, but about extension. Many prosthesis users consider their prosthesis indeed as an instrument, and not as a body part. One of the reasons is that the prosthesis provides imperfect mobility solutions. Another prosthesis user reports the following. "It [the prosthesis] is a tool in the sense that it enables me to do that which would be much more difficult without. [I wear a prosthetic] simply because it allows me to get from point A to B faster and easier than I could on crutches. It permits me maximum freedom of the choices available to me for mobility. And I like being mobile" (Murray 2004: 971).

The question that these fragments raise, is whether a more rigorous distinction between incorporation of non-corporeal objects into the body on the one hand and extension of the body by means of tools on the other hand could help us clarifying the difference in experience between tool use and incorporation, e.g. in the case of prosthesis use.

It may be useful to mention that I do not claim that tool use *always* is a matter of extension and never one of incorporation, or that prosthesis use *always* is a matter of incorporation. On the one hand, reports by prosthesis users show that satisfaction with a prosthesis is also possible if the prosthesis is experienced as a tool. On the other hand, music instruments, for example, may be experienced as closer to incorporation than to extension. A crucial factor in this is to what degree the attached object allows *expression.* The experience that expression is possible via a non-corporeal object might be decisive for experiencing it as a body part and not as a mere tool. Possibly, music instruments, which aim at altering or improving expressive capacities, form a separate category of extension/prosthesis.

The above thus shows that the distinction between tool and prosthesis is not rigid. The distinction we are searching for is the distinction between body incorporation and body extension, not between tool and prosthesis per se, since at least the latter can enjoy both statuses. How do we proceed now? We know that the transparency of the bodily supplement can be shared by both tools and prostheses. Consequently, the chief characteristic of incorporation must be found elsewhere.

3.3 Body Ownership as a Decisive Characteristic

A number of diverging contexts, ranging from phantom sensations (cf. Berlucchi and Aglioti 1997) to neonate imitation (Gallagher and Meltzoff 1996) and the infant's sensitivity for left-right reversal of their own legs shown on a screen (Rochat 1998; Rochat and Striano 2000),

motivate the introduction of a pre-existing body-model (Tsakiris et al. 2008; De Preester and Tsakiris 2009). Such a body-model would be decisive for what possibly counts as a body part and what does not, and it would thus constrain in a normative way what can be allowed to become a body part and what cannot be allowed to 'enter' the body as part of it. Moreover, it allows us to make sense of a number of major experiential differences between bodily extension and incorporation into the body.

Let us start with the rubber hand illusion (Botvinick and Cohen 1998; Ehrsson et al. 2004; Tsakiris and Haggard 2005), an experiment in which participants observe a prosthetic rubber hand being stroked synchronously with a stroking of their own unseen hand. The illusion that occurs is that participants experience the rubber hand as their own. It is only synchronous, but not asynchronous, multisensory stimulation that causes the rubber hand to "feel like it's my hand" (Botvinick and Cohen 1998; Tsakiris and Haggard 2005). In other words, in this condition, the participants have a feeling of body ownership over the rubber hand.

Yet, synchronicity of visual and tactile stimuli is not the only condition for the rubber hand illusion to occur. Three other factors constrain the effects of intermodal matching of seen and felt stroking: body specificity, anatomical constraints, and body part identity (cf. Tsakiris 2007; Tsakiris et al. 2007). Body specificity means that the viewed object has to be a body-part, and not a neutral object without any functional connection with the body. The anatomical constraints imply that the rubber hand has to be in a posture that is anatomically plausible, and congruent with the posture of the subject's own, unseen hand. And the constraint of body part identity means that the rubber hand has to be of the same handedness as the subject's stimulated hand (cf. Tsakiris et al. 2007: 649).

More generally, it can be said that the correlation between visual and tactile percepts (cf. the synchronous stroking) must fit within a body-model (cf. Tsakiris et al. 2007; De Preester and Tsakiris 2009), which acts as a top-down influence that limits the plasticity of representations of the body (Tsakiris et al. 2007; De Preester and Tsakiris 2009). The limits of plasticity thus seem to point to the stability of a body-model. This means that we cannot incorporate no matter what into our bodies, and that tool use does not automatically lead to a feeling of ownership over the body supplement. In other words, a feeling of ownership over a non-corporeal object is only possible when the normativity of the body-model allows for it.

Let us now turn back to the issue of incorporation versus extension. The body-model might be a decisive factor in determining what can be incorporated into the body. Incorporation into the body is not only a matter of integrated multisensory information—this also happens during tool use and can explain the phenomenon of quasi-transparency—but in addition to this and crucially for incorporation, it is also a matter of change in the feeling of body ownership. Bodily extension involves the integration of multisensory information such that sensorimotor capacities extend, together with a feeling of sensorimotor extension, but without changes in body ownership. In contrast, for something to become a body part, multisensory integration alone is insufficient, and a feeling of ownership over the bodily supplement is necessary.

A number of recent results suggest that the difference between tool use and incorporation is even more profound than expected. Whereas tool use induces an *extension* of the sensorimotor body, changes in body ownership are *not* a matter of extension. A recent study by Longo et al. (2008) not only paid attention to the experience of the rubber hand, but also to what happens with one's own hand, i.e. the hand doubled by the rubber hand. It turned out that in the synchronous stroking condition a feeling of paralysis of one's own hand and the experience of disappearance of the own hand is more present than in the asynchronous condition. Therefore, and firstly, the incorporation of the rubber hand does not seem to lead to an *extension* of the feeling of body ownership, but rather to a *replacement* of the own hand by the rubber hand. In short, the strategy followed by the incorporation of something

extra-corporeal into the body, is one of replacement rather than extension (cf. De Preester and Tsakiris 2009). It is therefore very unlikely that the famous 'third hand' of the Australian performance artist Stelarc ever becomes a true part of his body, although the extension is complicated in the sense that his prosthetic third arm can be moved independently from his own arms, and functions on the basis of muscle commands sent to his abdomen and his leg. Secondly, this difference may also elucidate a difference in experience. Ideally, the relation between a human subject and his or her limb prosthesis would be a relation of completion, i.e. a relation in which the subject makes an experiential whole with the replacement limb. Both amputees and people with congenital absence of a limb testify that a prosthesis indeed can become 'part of' the body in this sense. Here is the positive experience of a prosthesis user: "Well, to me it is as if, though I've not got my lower arm, it's as though I've got it and the prosthesis is part of me now. It is as though I've got two hands, two arms" (Murray 2004: 970). In the case of tool use, the relation is one of extending the body. It is important here that the tool does not come to replace a missing body part, and that the experience during tool use is not an experience of forming a whole with the tool (although the tool may feel as a quite natural extension of our bodies). Rather, it feels as if the tool is enhancing or indeed extending a certain bodily capacity, and not as if it is filling up a *lost* capacity.

Apparently, there are a number of good reasons for distinguishing extensions of the body and incorporation of something into the body. Many techno- and cyberfantasies do not take the profound differences between both into account. On the one hand, even intensive and long use of a limb prosthesis does not guarantee the strict incorporation of the prosthesis into the body. On the other hand, the body-model seems to prevent the possibility that tools and instruments that do not replace body-parts become a true part of our body.

4 Perceptual Prostheses and Extensions

Clark (2003, 2010), Clark and Chalmers (1998) defend the view that human minds, bodies, and sensoriums are open to possible re-structuring, in such a way that new equipment can become incorporated in the acting, sensing and thinking systems that we are. Before turning to the third category, the restructuring of human minds, I would like to pay attention to the second category, in which the human sensorium is being restructured. Transformations of the sensorium are commonplace, but the status of such transformations is rather unclear. One of the questions during a workshop on sensory substitution systems in Brighton (March, 2009, cf. www.esenseproject.org), is whether a distinction similar to the one in the domain of limb extensions and prostheses, is valid in the case of perceptual or sensorial transformation. Do we have the same issue here, namely that transparency in use is not sufficient for using the label 'perceptual prosthesis'? Is there something like a normative, constraining body-model for the sensory body as well? Or do sensory extensions, augmentations and improvements of the body imply a different 'logic', i.e. a different kind or reorganization, of the feeling of embodiment? One of the main issues is that in the case of perceptual prostheses, it does seem possible to go further than substitution (e.g. one modality for another), and to arrive at truly new forms of sensory embodiment. To explore this possibility, I will start again with the more familiar cases, and then turn to contexts where the problem becomes more poignant.

Perceptual prostheses or extensions alter our sensorium in that one of the senses is amplified or extended. The more familiar cases pertain to extension of the audiovisual, in the sense that instruments enable us to hear things from a distance, or make us see better than before. Sensory 'prostheses' that are very common are optics (spectacles, contact lenses) and, less

common but still widespread, audio technologies (hearing aids[5]). In other, equally familiar cases, vision or audition is being simulated (VR, computer games). But also communication media can be considered sensory 'prostheses'. For example, Alexander Graham Bell, the inventor of the telephone, wanted to make an amplifying device capable of transmitting a voice over distance, and intended the telephone as a prosthetic technology for the hard-of-hearing (cf. Ihde 2008, for a discussion). Much earlier in history, vision was extended by telescopes and microscopes. Nowadays, we are surrounded by multimedia technologies that make us perceptually telepresent. Perceptual 'telepresence' can be modest, as when we speak through the telephone, or it can be more elaborate, as in teleconferencing.

Most perceptual extensions or 'prostheses' are audiovisual. In general, vision and audition are more easily extendible than the other senses. The tactile, kinesthetic, gustatory and olfactory dimensions of perceptual experience are much more difficult to extend. Efforts are being made to overcome the audiovisual limitations and to evolve towards whole-body technologies that incorporate other senses, or even the full sensory spectrum.[6] Contemporary artists often play with this desire to arrive at whole-body technologies. One telling example is the *cyberSM*-project, by Stahl Stenslie and Kirk Woolford. This project premiered in 1993 and connected Paris and Cologne through the world's "first multisensory, full-body communication system" (cf. www.stenslie.net/stahl/). The participants could not only choose their own visual appearance, "it also takes the next logical step toward true telepresence by employing 3D graphics, live audio, and direct physical stimulation to allow participants to physically 'touch' each other over distances" (cf. www.stenslie.net/stahl/). The participants, wearing a body suit, see each other's virtual bodies on a monitor or projector, and by exploring and touching each other's virtual bodies, they can physically touch one another through the network. Less spectacular artistic efforts to overcome the audiovisual limitations include efforts to develop gustatory art, for example by the Norwegian odor artist Sissel Tolaas.

Another interesting field is VR, which differs from telepresence because in virtual presence the environment is simulated and not real. Nevertheless, we encounter similar limitations here: it is easier to simulate the visual and the auditory then to simulate other perceptual experiences. We can think here again of efforts to overcome these limitations and to simulate a multidimensional experience. This happens both in the further development of military technologies (e.g. flight simulators), the entertainment industry (e.g. games) and in the art world. *PainStation,* completed in 2001 by Volker Morawe and Tilman Reiff, is a noteworthy example in this context. Parodying *PlayStation, PainStation* is a videogame that inflicts pain on the player, and the new version even has adjustable pain levels (cf. Fuchs 2005; Rönnau 2006; see also www.painstation.de).

But, as Ihde remarks, although tactility and kinesthetic effects can be introduced in the medium (via body suits, wired gloves, moving seats), still the feedback found in full bodily engagement is lacking. As he rightly emphasizes, these extensions show a reduction/amplification structure, in the sense that some aspects of the perceptual experience, or some features of the experienced environment, are amplified, whereas others are reduced. For example, when I call my friend, my hearing is extended, but the full range of my sensorial experience of the other is reduced: "The other is only partially present, a quasi-presence or transformed presence. I am extended to the other, but the other is a reduced presence. This is, of course,

[5] For the difficulties in adapting to a hearing aid, see the account by Blondeel (2005), a Belgian sound artist with auditory damage due to overexposure to loud sounds.

[6] Also, developments in teleoperation aim at improving our ability to manipulate remote objects or environments (e.g. in remote surgery), and this often goes hand in hands with telerobotics. Here, however, technological developments aim primarily at extending the direct range of action, and therefore belong rather to the domain of limb extensions.

even true of the auditory presence as well" (Ihde 1979: 10). Even the auditory dimension itself is reduced or transformed: speaking through the telephone sounds 'phony'.

5 Subcategories of Perceptual Extensions

As the above illustrates, the status of the technologies that extend our perception is very diverse. A first category consists of instruments that gain a certain degree of transparency in use (spectacles, telescopes, microscopes, hearing aids, the telephone,). In Ihde's terminology, these are instances of embodiment relations. More precisely, an embodiment relation is a type of human-machine relation in which I experience the world or an object in the world *through* a machine (Ihde uses 'machine' in a very broad sense). Ihde's example of the piece of chalk is not from the field of primarily perceptual extensions, but embodiment relations are not limited to perceptual 'machines'. "The correlational structure of intentionality remains in that I do experience something other than the machine being used and at the same time my experiencing is extended through the machine for that intentional fulfillment. I may thus describe the chalk as having a partial *transparency relation* between myself and what is other. Likewise, I can use a language now which speaks of the machine as part of myself or taken into myself so far as the experience is concerned" (Ihde 1979: 8). Notice that the terminology wavers between speaking of 'extensions' and the machine as 'part of' myself or 'taken into' myself. Although Ihde adds here 'so far as the experience is concerned', this does not disambiguate the text. It might be that the characterization of the embodiment relation is too broad or vague to make a more clear distinction between extension and incorporation possible.

Another example of embodiment relation, but also not from the field of perceptual extensions, is the classical example of the expert driver and his car, and shows the same hesitation: "he 'feels' the very extension of himself through the car as the car becomes a symbiotic extension of his own embodiedness" (Ihde 1979: 8). However, what is most important in embodiment relations, is that the machine itself does not become objectified or thematic, but is taken into my experienc*ing* of the world.

Interestingly, perceptual instruments and tools like spectacles, telescopes, microscopes etcetera, can be characterized in a way similar (but not identical) to the way limb extensions are characterized. Thus, perceptual extensions are 'simply' extensions of the sensorium, i.e. a transformation of the sensorium that is strictly seen without accompanying changes in body ownership. This does not preclude changes in the feeling of embodiment or changes in embodiedness, but embodiment is a very comprehensive phenomenon, including both the feeling of body ownership and subjective feelings of embodiment related to the sensorium. Therefore, the vocabulary used should be precise enough, since it is unclear what a 'symbiotic' extension precisely is, or which changes in embodiment or embodiedness are precisely referred to. If something like 'incorporation' of the perceptual instrument or tool is meant, this seems, at first sight, unwarranted. On the other hand, the withdrawal of perceptual instruments is not always a matter of correlation between different sensory modalities, as in the case of limb extensions. The transparency obtained in many cases of perceptual instruments, rather seems to be a matter of attention, focus or thematization. Whereas I can easily focus on the feeling of the spectacles on my nose (something I usually don't do), such that the tool itself becomes the terminus of my experience, it is much more difficult to cancel established intermodal correlations (as in the case of limb extensions) such that the instrument came in the focus of our attention. Once we are an expert in car driving, e.g., it is very difficult to neutralize our expertise and to feel the car as when we were

learning how to drive. Generally, the transparency of limb extensions seems to be a matter of intermodal correlation (between the somatosensory and another sensory modality), whereas the transparency of the just mentioned perceptual instruments seems to be a matter of being directed not to the instrument itself, but to what it makes available for us.

That the nature of the relation is dependent on attention-related matters, is also clear from Ihde's own account, in which an embodiment relation (characterized by quasi-transparency) becomes a hermeneutic relation if the 'machine' itself requires attention and interpretation, and gains opacity. "Through the machine something (presumably) still happens elsewhere, only in this case the engineer does not experience the terminus of the intention which traverses the machine" (Ihde 1979: 12). Here, the machine has to be interpreted like a text (hence the name 'hermeneutic'). The change is nicely illustrated by the transition from light microscope to electron microscope. In the latter case, one no longer looks through the instrument, but a substitute 'eye' is used through photography, and the ensuing image has to be read and interpreted. In this case, the immediacy of the embodiment relation is displaced by the necessity of a hermeneutic process. Again, this distinction is not absolute: many of the apparatuses used in perceptual telepresence may waver between exhibiting a hermeneutic and embodiment relation, depending, e.g., on the degree of experience one has with the device, or on the degree of tiredness of the user.

Interesting cases of embodiment or hermeneutic relations are those in which the continuity with the features of the perceived world is no longer there. A good example is the discontinuity of infrared photography with ordinary, non-assisted vision. Here, a feature of the world normally inaccessible is available, and the 'intentionality' of the machine interferes with our own intentionality. This kind of experience can be strange. A work produced by Bruce Nauman shows this strangeness very nicely. In 2000, Nauman used infrared technology (an infrared digital video camera) for a series of video works with the title *Mapping the Studio (Fat Chance John Cage).* These videos literally let the spectator see in the dark. What we see are infrared images of Nauman's studio when he is not there, and we witness the nocturnal comings and goings of mice and Nauman's cat chasing them almost wearily. In spite of the strangeness of this experience, and although there is a discontinuity with the *features* of the world that we usually perceive, it must be noted that nature of our perceptual *experience* has not changed. In other words, although the range of features accessible to us is broadened, we have not obtained a new kind of perceptual experience. Ihde phrases it like this: "The photo ('text') remains continuous with the mundanely visible in that the features of the landscape are retained, the object is recognizable, etc., but a new feature has been brought into the horizon by using infrared" (Ihde 1979: 34). Thus, since the nature of our experience has not changed, we do lose access to some experienc*ed* features of the world if we turn off the camera or put off our infrared goggles, but in terms of experienc*ing*, we do not loose a perceptual capacity. My proposal is that as long as our experiencing itself has not changed, the label perceptual 'tool' or 'instrument' is more appropriate than the label perceptual 'prosthesis'.

A third kind of relation, next to embodiment and hermeneutic relations, can also be considered as a subcategory of hermeneutic relations, and pertains to the domain of imagination and image-consciousness (cf. Husserl 1980; Sartre 1936). I will not discuss this relation between an embodied subject and an image here, but it might be considered as a hermeneutic relation with a non-existent object in the position of the intentional object. An important difference with other hermeneutic relations is that it is not the machine that is experienced, or the image produced by the machine (as in the examples discussed by Ihde), but *through* the (mental or physical) image a non-existent world is experienced. Since we do not necessarily experience that the image has to be interpreted in order to view 'through' it into the imagined scene or

object, this is a reason for believing that image-consciousness and imagination are different from a hermeneutic relation, and constitute a separate category. In these cases, our vision is transformed, but a new kind of transparency comes into view: the transparency of the image itself.

Let us wrap up this overview and formulate some provisional conclusions. In his 1979, Ihde uses a terminology that manifests an unclearness similar to Merleau-Ponty's (1945) and subsequent research (with the notable exception of Heidegger 1962) on tools. The instrument, he says, is "taken into the observer's now extended self-experience. The instrument is experienced in use as a quasi-extension of the acting observer" (Ihde 1979: 71). He also speaks of a "partially symbiotic unity" which is "highly enigmatic" (Ihde 1979: 72). First, I have tried to argue that embodiment relations for perceptual instruments (category 1) are extensions of the body, and cannot be considered perceptual 'prostheses'. Second, the transparency obtained by perceptual instruments mostly is not a matter of intermodal sensory correlation, as in the case of limb instruments, but attention-dependent (whatever the mechanism of attention may be here). And third, the extension of the sensory body by means of perceptual instruments of this category does not imply any change in the way we experience, although new features may become accessible when using perceptual instruments.

Next, the difference between embodiment relations and hermeneutic relations for perceptual instruments is gradual, and covaries with the degree of transparency of the instrument or the image generated by the instrument. The more hermeneutic a relation is, and the more autonomous the machine is in generating images (or sounds), the more difficult it is to consider the instrument as an extension of our perceptual body. In these cases, the coupling between human and machine is much looser. Another important difference is that perceptual instruments in embodiment relations often amplify certain features already accessible to us without the instruments, whereas hermeneutic relations often make new features of the environment accessible. Again, this difference is not absolute, but gradual. Another factor of complexity is that a whole category of hermeneutic relations is not experienced as requiring interpretation at all. This is the case where perception is not extended, but simulated, e.g. on the basis of two-dimensional images or in virtual reality. Of course, that we normally do not experience our effort for interpreting images does not mean that there is no interpretation at all. Nonetheless, the notion of hermeneutic relations seems to point to the conscious experience of interpretation, and might therefore not be apt for this third category of perceptual transformation. It may therefore be better to speak of perceptual simulation relations.

Hitherto, none of the categories discussed seems to allow us to speak of perceptual 'prostheses'. In contrast, hermeneutic and perceptual simulation relations seem to move away from embodiment relations, and a fortiori from prosthetic relations. Yet, we have not discussed a fourth category, one that may bring into view the notion of perceptual prostheses.

6 Sensory Substitution

Sensory substitution is an interesting area of research for answering the question if it is possible to speak of perceptual prostheses. In sensory substitution, a device is mounted such that a subject has access to features of the world through an unusual sensory modality. Usually, sensory substitution devices convert stimuli of one sensory modality (e.g. light) into stimuli for another sensory modality (e.g. sound). In the latter case, the substituted modality is vision, whereas the substituting modality is audition. Originally, sensory substitution devices were developed in order to re-establish a lost sense (cf. Bach-y-Rita et al. 1969). At least in that sense, they are prosthetic, since they aim at substituting for a lost sensory capacity. In the

case of perceptual prostheses, the question is what the analogue would be of the alteration of the feeling of ownership that occurs in the case of limb prostheses.

By now, most of the developed devices convert images into sounds or into tactile stimuli.[7] In the former case, a kind of echolocation or image-to-sound conversion is used. In the latter case, images captured by a video camera are converted into electrical or vibratory stimulation applied to the skin (often the abdomen or the back, but also possible on the tongue or the forehead). In both cases, active control over the device is necessary to perform tasks that normally would require vision.

Part of the question if sensory substitution devices really re-establish a lost sense is to *which* sensory modality the acquired perception belongs. One position is defended by Hurley and Noë (2003) and is called the deference thesis. In this view, when the sensory substitution device converts visual stimuli into tactile stimuli, the experience really changes into a visual one. The opposite view (e.g. Prinz 2006) says that the experience remains tactile. This latter view is called the *dominance* thesis, since it is the substituting modality that dominates (see also Lenay et al. 2003, for a discussion).

An interesting position defended by Auvray and Myin (2009), is that we should move beyond the opposition between dominance and deference, i.e. beyond the understanding of sensory substitution as occurring in either the substituting or the substituted modality. Basically, they reject the presupposition that perception after sensory substitution is like perception in an already existing modality. "Rather, we will argue that SSDs [sensory substitution devices] *transform* and *extend* our perceptual capacities" (Auvray and Myin 2009: 1037, italics added). At first sight, this is not peculiar, since all perceptual instruments to some degree transform and a lot of them also extend our perceptual capacities. Their claim is nonetheless stronger, because what is really implied is that speaking of sensory *substitution* is altogether not adequate, or, that dominance/deference does not exhaust the possibilities. Moreover, it is clear that they do not simply have perceptual tools or instruments in mind, as the term 'prosthesis' or 'perceptual prosthesis' is repeatedly used (Auvray and Myin 2009: 1040, 1048ff).

According to O'Regan and Noë (2001), each sensory modality has a characteristic structure of sensory changes, or is, in other words, characterized by specific sensorimotor invariants. Applied to SSDs, the more sensorimotor invariants are shared with e.g. visual perception, the more perception with that particular kind of SSD resembles vision. From this point of view, perceiving with an SSD requires, just like normal vision, perceptual-motor learning. A second, related characteristic is exteriorization: without action, objects would not be perceived as located in three-dimensional space. "Indeed, studies have shown that, after training, the succession of proximal stimulations generated by the use of SSDs can be attributed to exterior and distant causes" (Auvray and Myin 2009: 1047, see also Lenay et al. 2003; Auvray et al. 2005). In other words, if the SSD converts light into tactile stimuli, the experience is not or no longer of a tactile map or image on the skin, but the cause of the stimulation is directly attributed to a *distant* object.

Importantly, Auvray and Myin (2009) refer to the blind man with his cane, who experiences the stimulation at the end of the cane rather than in the hand (where the tactile stimuli are received). "Similarly, the haptic experience of the contact with a tool, which is at first proximal can, after training, be projected to the end of the tool" (Auvray and Myin 2009: 1047; cf. also supra for an explanation of this). Thus, sensations recede to the background and experience becomes the experience of an external world.

[7] There is a whole range of sensory substitution systems, also for compensating the loss of tactile sensation, the absence of pain sensation, or the loss of proprioceptive information.

However, we have seen that correlation between modalities is characteristic of tool use or body extension, but not sufficient to speak of prostheses or the replacement of body-parts. Moreover, not all SSDs work on basis of a correlation between modalities. Many of them provide just one sensory input. The case of the blind man's case is a very complex one, because it is both a SSD and a limb extension.[8] That might be the reason why the example is both productive and confusing. So what is the difference between SSDs and tools? Is there another criterion that would allow us to label SSDs as perceptual prostheses rather than as perceptual extensions?

A more powerful criterion, on the basis of which the confusion between perceptual tool and perceptual prosthesis might be clarified, is the criterion of qualitative experience. According to this criterion, a sensory modality is characterized by a specific 'feel'. Reports about experience with SSD point to the idea that sometimes the experience does not belong to any known sensory modality, but to a new sense.[9] The idea that the use of a SSD can generate a new kind of experienc*ing,* is what might demarcate perceptual prostheses from perceptual tools, and might be the searched for analogue of change in the feeling of body ownership.

Interestingly, as in cases of limb prostheses, reports from SSD-users sometimes also suggest that SSDs are 'merely' tools. "In addition, an important finding was that the participants often emphasized that they simply had the feeling of mastering a new tool. They felt that they could easily acquire mastery of it because, as one participant said: "We are used to extending our bodies through machines, exactly as when we learn how to drive a car or how to use a computer"." (Auvray and Myin 2009: 1048). A questionnaire that focuses more specifically on the question if an SSD is, after training or prolonged use, experienced as extension of the body or as real body-part would be very informative here. Yet, the view that SSDs can lead to new kinds of experience is very challenging and a major argument for distinguishing perceptual instruments from perceptual prostheses. It could also help avoiding statements like the following,[10] according to which SSDs can lead to "an addition, augmentation, or extension of our perceptual abilities. Under this view, SSDs should be seen as tools that extend perception in entirely novel ways" (Auvray and Myin 2009: 1051). From the point of view defended here, the conflation of perceptual extension and novelty is inadequate, because perceptual instruments at most give access to novel features of the environment, not to novel ways of experiencing. In general, perceptual tools allow us to experience novel things, i.e. things that we could not experience or do without them. Following Husserlian terminology, I would like to call these novelties noematic novelties, because they pertain to the terminus of perception or action. Novel ways of experiencing, however, are noetic novelties, because they add a novel dimension at the side of experiencing.[11]

[8] The complexity of the blind man's cane is somewhat ignored by the deference thesis, in which the substituting modality (here touch) is overruled by the visual modality (the substituted modality) (cf. Hurley and Noë (2003). Thus, seeing without and seeing with a SSD that converts light to touch would be similar in that they are similar ways of exploring the environment. The correlation with the auditory is ignored here.

[9] In fact, the experience of the participants was mainly task-dependent. After training with a visual-to-auditory substitution device, some tasks were also experienced as resembling visual experience, others as resembling audition or even touch.

[10] One of the sources of the confusion might be that the authors consider our natural senses also as instrument-like, and on the basis of this view, both the natural senses and SSDs are considered as instruments. Cf. "Thus, just like our sense organs, seen as "organic tools," have led to our natural sensory modalities, SSDs might give rise to what could be called a novel sensory modality (subject to a sufficient degree of integration of SSDs to their users' bodily functioning, which might not be technically possible yet)" (Auvray and Myin 2009: 1054).

[11] The way I use noematic and noetic here, is different from Ihde's use in the context of tools and instruments. Ihde also talks about 'noetic' changes in the case of embodiment relations. In my view, no noetic changes occur

In short, and next to the requirement of transparency, there are reasons to think that we can speak of perceptual prostheses if (and only if) the absence or removal of the prosthetic device leads to a loss in the domain of perceptual experience at the noetic side. In that case, a sense modality brought about by the SSD and without equivalent in the natural senses is switched off. In contrast to limb prostheses, which are submitted to the normativity of a body-model, perceptual prostheses precisely seem to be characterized by the possibility to breach the confines of our usual ways of experiencing.

7 Mind-Enhancing Tools as Cognitive Prostheses?

In a seminal article, Clark and Chalmers (1998) ask the question where the mind stops and the rest of the world begins. In fact, the question is more specific: what can be recognized as part of a cognitive process? The authors defend the position that not all cognitive processes are in the head, and that also in the cognitive domain a human organism can be linked with an external entity in such a way that a coupled system arises. This coupled system, human + external entity, forms a cognitive system in its own right. That they form a cognitive system in its own right means that all the components in the newly formed system have an active causal role, and that together they govern behavior in the same sort of way cognition usually does. Thus, the claim is a strong one: the way human and external entity are related here cannot be adequately explained in terms of mere interaction with an external object. In contrast, the boundaries of cognitive processes do not stop at the skin or the skull, but can be extended, hence the notion of extended cognition. Moreover, extended cognition is not a simple add-on extra, but inherently pertains to human cognition. The external entities coupled to the human are manifold, and range from language and writing in general to calculators, Filofaxes, notebooks, and other memory aids, etc.

Clark and Chalmers (1998), (Clark 2010) develops the example of Otto, who suffers from loss of memory and relies on a notebook to help structure his life, and Inga, whose memory is intact. The claim is that the information in Otto's notebook functions just like the information in Inga's memory. In Otto's case, the information is reliably there, it is available to consciousness and available to guide action, just like the beliefs Inga has are reliably there, available to consciousness and available to guide action. Moreover, Clark and Chalmers claim that both cases are similar in all *important* respects, and that, consequently, nothing is sacred about skull and skin when it comes to belief. What makes some information count as belief is the role it plays.

Clark and Chalmers defend a functionalist point of view, and although what counts as important is itself debatable, their point of departure decides that only the functionally relevant features are important. In such a view, the phenomenology associated with the retrieval of information makes no difference to its status of a belief, because the phenomenological or the experiential is said not to be part of the functional. In such a functionalist account, subjective, first-person experience is ruled out beforehand. In the view that I would like to defend, the proposed functionalist account is not entirely adequate for understanding Otto's and Inga's cases. The reason is, that even apart from believing in the truth or falseness of some information (inside or outside the head indeed makes no difference), in order to function as a belief, it is important that an item of information is also, in a specific sense, *owned* by the subject. I have to appropriate it in some way, such that it

in the case of perceptual extension, and I consider the embodiment relations he discusses as a subcategory of perceptual or limb extensions.

belongs to my self. In other words, the belief should be 'mine' in order to function adequately as a belief. Of course, the 'mineness' should not be explicitly re-actualized each time I rely on the information or belief, but implicitly or pre-reflectively the mineness of the belief should be present. That Otto beliefs what is written in the book and is prepared to rely on it, that he recognizes the notebook as his own, and possibly also recognizes his own handwriting, is, however, not sufficient to make a belief one's own belief. I think that there are many ways in which information can be appropriated or become owned, and that an important factor is the understanding of the information. But since Clark's main case is about memory, I will focus on memory and use the idea of ownership of thoughts in the case he presents. I will not go into the mechanisms of ownership of thoughts (cf. e.g. Campbell 1999, 2004), or into the dysfunctions of cognition that follow upon or accompany the breakdown of the feeling of ownership of thoughts (Stephens and Graham 2000). The idea that I will use to argue that the difference in cognitive ownership between Inga's and Otto's belief has consequences for the functional role of the information, is the finding that information that is explicitly processed with reference to self enjoys a memory advantage over information encoded in relation to something not-self (Symons and Johnson 1997; Cunningham et al. 2008). This argument is related to objections answered in Clark (2006), but I do not think it is reducible to one of those refuted objections. It is also different from Ron Chrisley's developmental point, because his point is ownership of (future) implantable devices, not ownership of *thoughts* (possibly generated by such devices).

The basic idea is that owned items and non-owned items are processed differently. "Owned objects are believed to enjoy a special processing status (Beggan 1992) with such a strong association forming between self and owned objects that they are treated as psychological extensions of self and their perception is warped by pervasive self-protecting biases (Belk 1988, 1991)" (Cunningham et al. 2008: 313). Importantly, the special or even preferential treatment is not only applied to owned objects (that are perceived as, e.g., more valuable than objects not owned), but also to the encoding and storage of owned-object representation in memory. So owned objects are afforded an advantage in memory. The experiment in Cunningham et al. (2008) pertained to physical objects, and revealed a significant main effect of ownership such that self-owned items were better memorized than other-owned items. In other words, ownership elicits a strong memory trace (Cunningham et al. 2008; 315). Why ownership favors memory is difficult to say. One interesting suggestion is that owned items prompt attentional resources to be directed towards their encoding or retrieval (Cunningham et al. 2008: 315).

Let us now return to the case of Inga and Otto, and suppose that the above is not only valid for physical items or their mental representatives, but also for thoughts and beliefs themselves. In what sense can we say that Inga and Otto own their beliefs? The way the information is accessed differs in important respects. I don't want to repeat the arguments about external perception (Otto) and introspection (Inga) here, because that is not my point. My point is rather that Otto has to re-appropriate his belief each time he needs the belief at stake and looks it up in his notebook, whereas Inga is in a position in which her implicit ownership is not only made explicit when she retrieves a belief from her memory, but also reinforces her ownership over the thought each time she retrieves the belief. My claim is that Inga has a stronger ownership over the informational items in her memory than Otto, and that therefore the information in her memory functions differently from the information Otto has in his notebook. Ownership and memory seem to reinforce each other, and since Otto is in an unfavorable position (since he suffers from memory loss), we cannot say that he owns his beliefs in the notebook in the same way

Inga owns her beliefs. This may also be a reason why an implanted chip with information could not function in the same way as information over which we have cognitive ownership.

If it is true that owned items are processed differently from items that are not owned, this might have consequences for the idea of extended cognition as well. Surely, the feeling of mental ownership over a thought or belief is a matter of subjective experience, but it is also correlated with a different way of treating the information than non-owned items. I think that Clark should argue that Otto mentally or cognitively owns his beliefs in the same way Inga does, such that we can assume that Otto and Inga process their beliefs in the same way. One way of doing this is by arguing that cognitive or mental ownership can extend to external information, perhaps in a way similar to the way we can acquire body ownership over non-bodily things. If not, the coupling between cognitive agent and external devices is at best comparable to the way we relate to instruments. So my point is not that extended cognition is impossible, or that intense couplings between the human subject and environmental items would not enjoy a special status. But I think that we should remain faithful to the idea of *extension* in extended cognition, and set stricter our criteria for speaking of future cognitive *prostheses*. So, the idea that we are natural-born cyborgs should be distinguished from the idea that I defend here: that we are natural-born tool-users and that our expertise with tools implies an ability to manipulate highly complex instruments, of both technological and cognitive complexity. Real incorporation with concomitant changes in ownership or perceptual experience is much more difficult to obtain, exhibits fewer degrees of freedom than tool-use, and obeys regularities of its own.

8 Conclusion

I have argued for a more rigorous distinction between body extensions on the one hand and incorporation of non-bodily objects into the body on the other hand. Real re-embodiment would be a matter of taking things (most often technologies) into the body, i.e. of incorporation of non-bodily items into the body. This, however, is a difficult process often limited by a number of conditions of possibility that are absent in the case of 'mere' body extensions. I have discussed three categories: limb extensions/prostheses, perceptual extensions/prostheses and cognitive extensions/prostheses. For each category, I proposed a distinction between extensions and incorporations, and suggested the conditions of possibility for real incorporation. These conditions of possibility differ in each category, but in general they ask for radical or fundamental alterations not only in the motor and/or sensory constitution of a human subject, but also in his subjective experience. In the case of limb prostheses, the crucial factor is a change in the feeling of body ownership. In the third case, cognitive prostheses, it is also a feeling of ownership that is at stake, but this time it is about ownership of thoughts. In the second case, perceptual prostheses, a change in subjective perceptual experience is the central issue.

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