Robotic prosthetics: beyond the technical performance

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A study of socio-anthropological and cultural phenomena influencing the appropriation of technical objects interacting with the body.

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While physical interaction with robots is becoming common in many domains, numerous devices are not appropriated by their users and remain unused in the cupboard. This phenomenon is particularly observed with robotic devices which interact closely with the body, especially if they are designed to compensate for a loss of sensory or motor capacity. This article uses the quite extreme example of prosthetics to highlight the socio-anthropological and cultural phenomena affecting the appropriation and use of technical objects which interact with the body as much as (or even more than) their technical performance. Considering these complementary points of views and theories in the design of such devices could be a way of improving their appropriation.

I. INTRODUCTION

There is currently an explosion in the number of devices being developed for interaction with the human body, especially in the field of robotics. This is reflected by the recent increase in the number of publications in the field of "pHRi" (Physical Human Robot Interaction) [1]. This results from several recent technological advances in control techniques and sensor technology (in order to be more sensitive to the actions of the user, for example), and the introduction of compliant mechanisms (using Variable Impedance Actuators VIA or software-based elasticity generated by the control mechanism) in robotic structures [2]. All these developments have led to a matching of the physical and motor characteristics of robots with those of the human body, making them safer and therefore promoting the development of closer physical exchanges. There are numerous fields of application in which technological devices interact "on", "with", "against" or "inside" the body: eg surgery, rehabilitation, substitution and assistance (see Fig. 1 for illustrative examples) whether it is for people with partial loss of motor skills or to increase the physical capacity of healthy subjects (generally strength or endurance).

Relationships between the body, techniques and technology[1] have always been a fundamental topic of research for humanities and social sciences, especially the field of anthropology of technology. This field encompasses the history, purpose and roles (whether they are real, symbolic, mythological or religious) of technical objects. One of the aims of this field, which developed from the study of the process of human evolution through the use of tools, is to study the relationship between human beings and the tools and techniques they have created, as well as the impact that these tools or techniques may have on the process of civilization and the creation of culture.

Historically focused on the study of prehistoric civilizations, anthropology has naturally been interested in the so-called "primitive cultures" (which generally developed civilizations and levels of technical and symbolic sophistication similar to our contemporary occidental civilization). The same tools and approaches initially developed for the study of these primitive peoples are now used by anthropologists to study contemporary civilizations. Therefore, for example, the relationship between a surgeon and the particular tools he/she uses [8] can be studied in the same way as the relationship between a prehistoric man and his biface and other flint objects, or the Baruya tribe (Papua New Guinea) and their axes [9]. However, the anthropology of technology is not limited to the study of "extraordinary" objects and the specific expertise they require, confining their use to a small fringe of the human population. It also considers common "everyday life" technical objects. Anthropologists therefore study relationships with, and symbolic aspects of, objects for which the technological aspect is not the main feature: this could include blue jeans [10], a fork [11] or, of course, the New Information and Communications Technology (NICT) devices [12], particularly their relationship with human body.

The focus of this paper is on the specific example of functional robotic upper-limb prosthetics. The purpose is to emphasize the complexity and diversity of socio-anthropological and cultural phenomena which affect the appropriation and use of technical objects interacting with the body. The second objective is to highlight how appropriation of prosthetics may be improved if technical staff (engineers and researchers) considered these concepts and theories during the design stages.

II. BACKGROUND: AMPUTATION AND UPPER-LIMB PROSTHETICS

A. Upper-limb amputation and prostheses

People who are disabled following acquired or congenital amputation of the upper limb are usually fitted with an external prosthesis, or "orthoprosthesis", especially the young and active persons [13]. The main etiologies which lead to surgical amputation are trauma (road traffic accidents, accidents at work, or war injuries), malignant tumors, vascular accidents or infections, and, diabetes [14]. Whatever the cause of the amputation, the loss of one or both upper limbs has huge consequences on the person's capacity to carry out activities of daily living as well as impacting their professional life and autonomy. Amputation is considered to be a public health issue because of *"the repercussions of the deficit related to the loss of all, or part of, one or both upper limbs on socio-professional and family life"* [15]. This is consistent with the analysis of disability conceptualized by the International Classification of Functioning, Disability and Health (ICF) [16].

Three different types of prostheses are currently available to patients: non-functional (cosmetic) prostheses, and functional ones, among which (see Fig. 2) mechanical prostheses (controlled by the remaining joints or the opposite limb via a cable) and myoelectric prostheses which use surface electromyograms (sEMG) of the voluntary electrical activity of the residual muscles of the stump to control the electrical actuators of the prosthesis. The latter are commonly placed under the term "robotic" prostheses although "robotic" prostheses relate to recent myoelectric prostheses that integrate automation (eg automatic tightening of the hand when a grasped object begins to slip) or advanced control technologies (such as the automatic posture generation offered on recent polydigital hand prostheses).

Commercial companies mostly propose hand and forearm prostheses for forearm amputations (the most common upper limb amputation), as well as a few elbow prostheses. Naturally, because of the small size of the market, there are fewer prostheses for transhumeral (above the elbow), and even less for higher levels of amputation.

Most research institutes and companies focus on improving the hardware of hand devices, the design of which is coming closer to that of humanoid robotics limbs [17]. Several polydigital myoelectric hand prostheses (with more degrees of freedom than the traditional opening/closing hand) are already commercially available. Nonetheless, rigorous clinical studies of the performances and advantages offered by these devices are still lacking.

B. Recent technological advances

Beyond improvements in hardware, significant progress has been made in both devices developed by research laboratories and commercial prosthetics, regarding control techniques; sensory feedback and also the development of new materials.

For example, researchers from the Rehabilitation Institute of Chicago (RIC) have developed an innovative surgical technique termed "targeted muscle reinnervation". This technique involves the surgical rerouting of motor nerves of the sectioned limb to a group of surgically deinnervated muscles in the thoracic wall [18]. Following a learning process, the subject controls these muscles exactly as he/she controlled the missing limb. Electrodes are implanted within the muscles in order to capture the EMG signal sent by the brain which thinks it is controlling the arm. This signal is then used to drive the prosthesis. This method can be used to control prostheses with a large number of active joints, avoiding sequential control (joint by joint). More recently, electrodes have been implanted in the cortex of the brain of tetraplegic patients with a total loss of mobility. During these short-term trials (1 month for ethico-legal reasons), including an intensive learning phase, the patients were able to use an external robotic arm to carry out activities of daily living [19].

Sensory information is essential for the performance of motor activities (in neurosciences the term sensory-motor control is used, rather than motor control). Much research is therefore focused on restoring sensations of interaction of the prosthesis with the environment. The aim is to improve fine control (such as the degree of force exerted by the hand), and to reduce the necessity for intense visual control. The technique involves placing force/pressure sensors in the prosthetic fingers and returning the information to the patient via another modality (usually vibro-tactile) to the residual part of the limb [20]. An alternative invasive approach has recently been tested on one patient: in [21], information on touch and interaction forces measured on a prosthetic hand was translated into electrical stimulations sent to electrodes directly implanted into the peripheral nerves of an amputated patient. Using this sensory feedback, the blindfolded patient was able to recognize different objects by their feel and shape and to adapt his grasping strategy accordingly.

Several less « robotic » innovations, have also improved the quality of prostheses as well as their comfort. The use of new materials (plastic, composites, light metal alloys) has significantly reduced the weight of prostheses compared with old-fashioned ones made of steel, PVC and, until recently, wood and leather. Silicon suction sockets simplify donning of the prosthesis (in some cases, avoiding the use of harnesses and straps), providing a better fit and limiting problems relating to irritation around the stump. The use of silicon as an alternative to PVC, which is usually used to line prostheses, has the advantage of being able to create ultra-realistic and customizable prostheses, reducing the visibility of the disability.

C. Contrasts between technological advances and real use of prostheses

Despite these numerous technical advances, several facts can be noted, particularly when comparing current devices with older ones. Firstly, there is a large discrepancy between the number of research teams working on the development of robotic limbs in laboratories and industry, and the number of limbs which are currently commercially available. This demonstrates the complexity of the technological transfer of products destined for a very small market, with little economical attraction. Secondly, it is surprising to see that there has been very little conceptual change in prostheses since the beginning of the previous century (particularly those developed following the First World War during which the atrocious injuries led to remarkable progress in medicine, surgery and prosthetics), or even since the renaissance period (see Fig. 3).

This technical stagnation is corroborated by clinical observations. According to clinicians, there has been no, or little, positive change with regard to the appropriation of prostheses by patients. This contrasts with a report on external upper limb prostheses carried out by the French Health Authority in 2010 which underlines that, despite technical difficulties, use of a prosthesis improves functional independence and quality of life in upper limb amputees, however, almost a quarter of upper limb amputees do not use a prosthesis [15].

Moreover, there is a lack of interest in technology by users, and sometimes even total rejection. Clinicians are regularly confronted with users who, after having tried a recent myoelectric prosthesis, prefer to go back to a mechanical cable-based device or even a purely aesthetic limb.

D. The prosthesis: an ultimate/ technical object

This observation is, actually, not very surprising. The anthropology of technology, among other fields, has shown for a long time that many phenomena other than technical performance, condition the appropriation and use of a technical device, particularly when the device is designed to interact with the body.

During the previous century, a large number of thinkers pondered over the relationship between the body and technology. The aim of this article is not to present a history of the very rich field of the anthropology of technology; this would be pretentious given the complexity and the range of the work which exists in this field. All the same, it is impossible to take an active interest in the technical object which is the prosthesis, without considering the work of M. Mauss, A. Leroy-Gourhan, G. Canguilhem and G. Simondon, and to highlight the importance of taking their thoughts into consideration in the conception of better technical objects.

More than a pure technical object, prosthesis is both “body”, and a “body-technique”. It is body in the sense that it physically replaces part of the body, and a “body-technique” [22] since it requires learning and the use of new body techniques. Moreover, it is intimate and permanent, at least in the sense of its vocation. It is used intensively in the home (which is rare for a robotic device since the only robots which have entered peoples’ homes are service robots which do not need to have such a high level of functioning and reliability) and by users who could, at first sight, be considered as “non-experts”. Lastly, and this is particularly true for upper limb prostheses, it is visible to others. Thus, viewed in the light of the work of these thinkers in anthropology of techniques, the prosthesis can be considered as an ultimate technical object.

This article therefore describes socio-anthropological and cultural phenomena, which have as much influence on the appropriation and use of prosthetic devices by patients as technical performance.

III. Beyond technical performance

A. Disciplinary compartmentalisation

It is surprising to note that prosthetic “technicians” (researchers and engineers) have given little consideration to the fundamental work from humanities and social sciences on body and techniques. Although the work of M. Mauss [22] highlights the importance of “body techniques”, the new action and gestures which are necessary to use a prosthesis, and the learning process involved are rarely considered in the design. Mauss used a holistic approach to broach the biological, psychological and sociological aspects of human beings, however his method is rarely followed. Indeed, despite the fact that the role of prosthetics is to replace a part of the body, they are generally only considered from a “biological” point of view.

The work of A. Leroy-Gourhan [23] on the technical, psychic and psychological relationships between man and techniques during prehistoric periods (particularly regarding the process of hominisation), is little known in the world of robotic “tool” conception, despite the fact that it has influenced fields such as the neurosciences.

G. Canguilhem’s work on normality and the process of construction of biological difference [24] is also rarely considered, despite its pertinence when trying to normalise a “lessened” body. The mechanistic view of the body which dominates the field of engineering (in an often simplistic form) would benefit from an evolution towards the “vitalistic” vision defended by this author. Indeed, he proposes a more complex vision of the body from the perspective of its relationship with its environment.

Lastly, it would be pertinent to reconsider prosthetics, their conception and their use in the light of the work of G. Simondon [25]. This work suggests that a prosthesis is indeed an ultimate object since it is both a “tool” (allowing action on matter) and an “instrument” (transforming perception of matter); and its concept of the cultural and “human” existence of technical objects would provide a more global approach to the genesis of these objects for prosthetic designers.

B. Ambient cultural myth

We are currently living in an era in which there is a very pervasive mythology of a particular chimera termed the “cyborg”, and of man-machine hybridization. A large number of cultural products from science-fiction nurture this myth and influence the manner in which we perceive technology: the ambient cyborg myth generates a discrepancy between collective imagination and technical reality. In the case of prosthetics, this mythology thus generates a perceptive bias, responsible for changes in technical values and leading to a sensation of deception in a large number of prosthetic users.

This phenomenon raises the question whether such a myth reduces the stigma of amputation by trivializing the image of a prosthesis wearer, or if, in reality, the over representation of a repaired, or hybrid, body does not have the reverse effect, even perverse, by constantly exposing the image of a super human, or an “athlete-come-hero” (see O. Pistorius [26]). It is indeed the face of a “monster” (in the sense given by the philosopher M. Foucault [27]: unclassable, displacing the limits of normality), which is particularly present in the majority of these mythical works, rather than the “ordinary” prosthesis-wearer, amputated following an accident at work, for example.

This over-representation and simplification of the “cyborg” concept generates a form of misoneism, a rejection of innovation and technology, an indirect source of passion around the question of prosthetics, when there should only be reasoned thinking (a “for or against” debate regarding wheelchairs or crutches would seem incongruous).

The patient, reduced by the act of amputation, more or less fixed by the prosthesis thus finds himself thrown, out of his will, into the middle of passionate debates on the questions and risks of an “augmentation” of his/her body, which he knows is far from being technically possible.

C. Versatility and technical popularization of performance

Another important phenomenon related to the appreciation of technology is the discrepancy between the versatility of the human body and the popularization of technical performance.

The body can carry out a fantastic number of motor actions. This is particularly true for the upper limb whose capacity ranges from tasks which require large forces (e.g. carrying boxes, lifting your own bodyweight, etc.) to very fine tasks requiring much dexterity (playing the piano, writing, etc.) as well as dynamic tasks (catching a thrown object) and all this repeatedly (endurance). However, this versatile nature of the body, its capacity to carry out so many different tasks (with more or less success), is often forgotten.

Versatility is a rare performance index in the different fields of engineering, for example robotics. Indeed, the mechanistic and functionalistic tradition which governs this domain tends to decompose the technical object into sub-functions. This functional decomposition leads to a segmented evaluation of performance, which does not allow the capacities of a technical object to be extensively compared with those of the human body. The performance of these technical objects is thus generally simplistically evaluated as the capacity to achieve the function for which it was defined. This performance, although “local”, tends to be deformed or generalized when it is subjected to the process of scientific and technical popularisation. Thus, the fact that artificial intelligence beat the human mind in a game of chess, induced the (false) notion that artificial intelligence performs better than man, in the minds of a part of the public. It is this same deformation which leads the public to fantasize the real capacities of robotic objects, by extrapolating and generalizing their temporary capacity to carry out a task more efficiently than a human being.

Prostheses, like other technical objects, incur this phenomenon. The debated concept of “the augmented man” is, for example, a direct consequence of this phenomenon in the sense that existing augmentations, which are the subject of much thought, are far from being complete “augmentations”, but are rather “local” augmentations, only effective for very specific tasks. Oscar Pistorius can thus run faster than most of mankind with his carbon blades (Cheetah from Ossur® [28]), but he needs “ordinary” anthropomorphic prostheses to be able to stand without having to jump on the spot, and to be able to walk slowly without scraping the ground.

This popularization of a localized, generalized technical performance and the forgotten versatility which is the primary characteristic of the human body induces a certain amount of perplexity in amputees and tends to increase their dissatisfaction with their prostheses. Flicking through a catalogue of lower limb prostheses can give a good idea of how far this phenomenon extends: in the hour in which the term augmentation is used in relation to lower limb prostheses, different prostheses are required to be efficient in different domains (running, walking and climbing, for example).

D. Level of perception of technical objects

Another influent phenomenon relates to differences in the perception of technical objects between different groups within the population, as well as within each group. The prosthesis as a technical object can be viewed from many angles. Thus if we study the semantics used by the different groups who have contact with prosthetics, to qualify this technical object, large differences can be observed (following results were obtained during interviews with amputees fitted with prostheses in the Regional Institute of Physical Medicine and Rehabilitation (IRR) in Nancy). The user group uses expressions such as “practicality, slow, heavy, disabling, expensive, and restrictive”, particularly if the interviewer is identified as belonging to the technical staff group. This latter group uses more generic terms such as “performance, fragility, manufacturer, guarantee, possible adaptations, etc.” which could characterize any type of machine. Lastly, when the “public” is asked to discuss prosthetics, the themes which arise generally converge around the futuristic and technological aspects, quite frequently with passionate opinions which oscillate between fascination and perturbation (see the passionate debates aroused by the ambient cyborg myth and the lag between augmentation and technical reality).

All the same, and this is the important point, perceptions vary greatly within the same group. The person’s personal history, their amputation, family, social and professional life are all elements which participate in the definition and shape of a person’s relationship with his/her prosthesis. Thus, within the group of prosthetic-users, some will view their prosthesis as part of their body, and others as a quite separate tool (particularly manual workers or those in the primary sector). There is also ambivalence between its nature as a "mask" and the "stigma" which is quite present, particularly for those with aesthetic prostheses. Lastly, some patients describe their prosthesis as an external entity, sometimes a partner, sometimes an adversary, with which they are engaged in a sort of "social" relationship.

The public perception of prosthetics –largely deformed by the recurring concept of augmentation– errs between fascination and rejection, and this study of course is a reminder of the complexity and the ambiguity of the social representation of disability, underlined in the 90s [29]. Above and beyond the technical object, and in the case of prosthetics, much more than for other technical objects which interact with the body, it is normality which is questioned. Thus, even if it is tempting to organize and to categorize the phenomena of representation, the large number of studies carried out on *labelling theory* [30] and on stigmatization reminds us of the limits of such simplifications.

The validity of categorizing people in groups as is sometimes proposed in simplifications of prosthetic specifications can be questioned. Beyond quantitative facts and the group within which the person is categorized, it is the whole-person which needs to be considered in order to foresee and understand the appropriation or not of a prosthesis.

E. Use, conception and acceptance

The questions evoked above, regarding certain simplifications of the representation of the "target" in the process of the conception of prosthetics highlights the fact that there are several problems with the definition and conception of this technical object.

First is the fact that the approach to conception is ill adapted, tending to consider the object and its technology rather than the related technique or use. This is particularly problematic in the case of prosthetics, technical objects which require the introduction and learning of new body techniques.

This lack of consideration of use as described in a large number of studies on the conception of technical objects [31], tends to cause another phenomenon: the belittling of the expertise of the user, and more particularly, the disabled user. The arduousness of the decomposition of a gesture into a sequence of movements (often necessary in the case of myoelectric prostheses with several active joints), the complexity of controlling one (or several) joints through the contraction of completely different muscle groups, the necessity of constant visual control to compensate for sensory and proprioceptive loss, and lastly, the cognitive load generated by the high level of concentration required to generate contraction signals which can be understood by the prosthesis make the user an expert in the use of his own body, in the same way as a surgeon is considered to be an expert with his hands.

The lack of consideration of these issues in the conception process, leads to compensation by calling upon humanities and social sciences at the last minute. The concept of acceptance to which the designers of technical objects refer, is thus more often than not an a posteriori sterile justification rather than a prior-to-conception real consideration of the needs and uses of the user and related anthropo-socio-cultural issues [32].

Lastly, the complexity of the questions raised, once again, highlights the importance of the consideration of the results of anthropological studies in the conception and design of prosthetics, as much as those from quantitative/statistical sociological approaches which can appear more easily exploitable in engineering processes because of their "mathematical" content.

F. Integrity and integration

Beyond anthropological and social issues, a number of phenomena related to psychology and the neurosciences influence the appropriation of prosthetics. Two important questions can be posed when proposing prosthesis for an amputee: that of the physical integrity of the amputated body, as well as the physical integration of the technology.

The amputated and thus (we could say "de facto") diminished body questions the notion of physical integrity: the damage made to the sacred envelope which is the human body alters the representation which the subject has of himself and can harm his self-perception. This notion of physical integrity is, nevertheless, still far from being completely understood: although the injury to the "body-schema" has been clearly identified in traumatic amputees (who evoke a "diminished body"), it would appear that some patients with amelia (born without one or more limbs) feel quite complete.

The relationship between the assault on the skin and that on the psyche, a classical subject in psychology, should obviously be considered in order to understand the effect which the prosthesis could have on its wearer. The body envelope holds a high psychological importance, and the simple act of inserting a needle in the skin has consequences far beyond the physical aspects. It is thus easy to imagine that the intimacy of prosthetic fitting and electrode implantation (in the case of a myoelectric prosthesis) can have a direct psychological effect on the patient. Above and beyond the fear of pain, complex symbolisms relating to the "invasiveness" of a prosthetic device which crosses (recent prototypes use cortically implanted electrode grids) or comes very close (myoelectric prostheses use surface electrodes) to the symbolic barrier of the skin can directly affect the user's psyche.

The phenomenon of the physical integration of technology thus has psychological aspects but in order to fully understand it, one must also look to the neurosciences and social sciences. Indeed, when different research communities are questioned on the conditions required for the integration of prosthesis in the body image, opinions differ, and even the possibility of complete integration is questioned. For neuroscientists, the relationship between sensory-motor loops and physical integration appear obvious. Several studies have demonstrated this: research on the subject of the physical integration of vibrotactile devices used to substitute visual loss [33]; work on the development of the sense of orientation through long-term wearing of a "compass-belt" which provides constant vibrotactile information on the direction of North [34], or the "rubber hand" experiments in which the combination of sensory signals (visual and tactile) generate the sensation that a rubber hand is a part of the subject's own body [35].

Of course, the creation of these new sensory-motor loops requires a learning process which could also be one of the keys to the physical integration of a technical object [36]: in the same way that a sculptor will over the years of use, displace the boundary of his body beyond his tool which becomes an extension of his hand, the intensive use of a prosthesis will ensure that gestures become automatic, favouring physical integration.

Beyond these neuro-physiological phenomena, it is impossible not to consider the conditions required for the incorporation of the technical object in the light of work from social integration theories. As M. Merleau-Ponty stated "t*hey are therefore not reflexes, automatic reactions and even less "images" or mental representations which are incorporated, but "typical" behaviours, that is to say, ways of doing, seeing, thinking, of the people we regularly frequent*" [37]. The manner in which society perceives, considers and judges the prosthetic-user is thus also indirectly responsible for the level of personal appropriation of this technical object which, like amputation, remains a stigma.

Integration of the prosthesis by the amputee is therefore directly conditioned by the integration of the prosthetic-user in society, another demonstration of the "holistic" nature of this phenomenon.

G. Temporality and instantaneity

Another society-driven myth, apart from the cyborg (although it is related), is that of instantaneity. Socio-cultural productions promote, as well as the image of a hybrid body, the (utopic) idea of instant integration: the "augmented" man, newly amputated and equipped with robotic limbs can straight away make full use of the capacities (motor and sensory) of these devices. The direct consequence of this myth is the negation of the difficulty to learn body techniques and the time scale required: this comes to forgetting the number of years it took us to master our bodies for basic tasks (balance, walking, grasping etc.) and then to acquire (sensory)-motor expertise (sport, piano, arts, etc.). With regard to prosthetics, this utopia of instantaneity has a negative effect both on users as well as the designers of technical devices.

The amputee is thus usually surprised at the difficulty he has to learn to control his prosthesis (forgetting that he took several years to master the now lost limb), and this lag between myth and reality can be discouraging in some cases, pushing him to request a more simple device (cable-based mechanical prosthesis, or even simply aesthetic).

This negation of the temporality of the learning process leads the prosthetic designer to sometimes conceive technical objects which require body techniques which are so new and/or complex that the learning time is longer than the lifespan of the device itself (temporal incompatibility between learning and obsolescence).

H. Ethical questions

A large number of studies have been carried out by different groups regarding the ethics of technology, in particular, when the aim is interaction with the body. Several ethical think tanks have produced norms and legislation regarding these questions. For example, the European Ethics Group on science and new technologies lists several main –but quite generic– points in its report on the "Ethical aspects of NICT (New Information and Communication Technology) implants in the human body": respect for human dignity, inviolability of the human body and physical and psychological integrity, protection of private life, non-discrimination and equality, principle of precaution, etc.

These legislative points are not to be ignored, however, they should not be considered alone, disconnected from technical reality and anthropo-socio-cultural phenomena: the impact of techniques on human beings is more complex than the legal questions and biomedical aspects which are generally at the forefront of this type of work. There are currently only a few objective entities and research groups working on broader questions than the legal aspects, much work comes from highly active trends which favour rather far-fetched man-machine hybridisation. These post-humanist or transhumanist trends (H+ magazine, Singularity University) prone –to different degrees- an unlimited use of technology and man-machine hybridisation in order to push mankind beyond its biological condition. These groups, which exploit the ambient cyborg myth and benefit from the support of many personalities within research and industries in the fields of NICT, have a large capacity for communication (particularly to the public), occupying, among others, the domain of thoughts on the relationships between body, technique and technology which normative ethics struggle to occupy and popularize.

IV. Conclusion

In this article, we showed that progress in technology alone will not solve the issue of appropriation and integration of robotic objects, especially when they interact with the human body. This article provides an overview of major socio-anthropological and cultural phenomena which influence the close interaction between human beings and technical objects, using the example of the prosthetics.

Most of these considerations can be applied to other robotic devices dedicated to pHRi (surgical robots, exoskeletons, wheelchairs, cobots, etc.). We strongly believe that an awareness of this multitude of phenomena, symbolisms and points of view could help technology researchers to produce better adapted technological devices.

Moreover, at a time in which there is an increase in studies relating to the ethics of research on robotics, this study pushes us towards another "ethical" question: that of the technical deontology of the conceivers of these objects. Indeed, only the adoption of a global or "holistic" point of view, which neither neglects nor denies any aspects of the problem, and which results in a concrete, ecological approach to co-conception, could be considered truly ethical.

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Footnotes

1. *Contrary to other languages, there is usually no distinction in English between the word "technique" and "technology". Nevertheless, in the field of humanities a distinction is generally made between technical objects (eg a tool), the technique (or technical process, eg. the knowledge and method required to use a tool) and the technology which is the logical study of both technical objects and techniques [8].*

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Figures

Fig. 1.

Fig. 2.

Fig. 3.

Figure legends

Fig.1. Examples of applications in which robotics devices physically interact with the human body: surgery with minimally invasive telesurgery with the DaVinci robot ©[2015] Intuitive Surgical, Inc.[3]; neuromotor rehabilitation of the upper limb following a cerebral vascular accident with the Armeo®Power from Hocoma, Switzerland; substitution with the JACO device from Kinova [4] which is fitted to a wheelchair and help the person to carry out activities of daily living; and finally assistance with lower limb exoskeletons for paraplegic patients (with the Rewalk system [5].) or for healthy subjects in military and industrial applications (with the the Berkeley Bionics HULC - Human Universal Load Carrier [6]).

Fig.2. A soldier in the U.S. Army plays fooz-ball with two prosthetic limbs: one mechanical (right arm) and one myoelectric (left arm). Courtesy of the U.S. Army, by Walter Reed photographers.

Fig.3. From left to right: Artificial hand, from Ambroise Paré's Instrumenta chyrurgiae et icones anathomicae (Surgical Instruments and Anatomical Illustrations), Paris, 1564. Artificial iron arm from the 16th century. First World War artificial left arm with shoulder straps. Made with leather and aluminium by W. R. Grossmith.

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