Relations That Constitute Technology and Media That Make a Difference: Toward a Social Pragmatic Theory of Technicization

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1. What is Technology? A Change of Views

Technology is usually defined as tools made by humans, as efficient means to an end, or as an ensemble of material artifacts. But technology also encompasses instrumental practices, like the creation, fabrication, and use of means and machines; it includes the whole ensemble of material and non-material techno-facts; it is closely connected with institutionalized needs and ends-in-view that technologies serve. (For broader views, see Mitcham, 1978, and Hannay and McGinn, 1981; see also Ropohl, who restricts the definition of technology to material artifacts, their human production, and their purposeful use.) When authors include a wide range of aspects in their view on technology, they think along the lines of an old and well-established tradition. Since the times of Aristotle, four elements are discerned which constitute technology: the first element is the stuff or material, out of which a techno-fact is made; the second element is the form or shape, that is given to it; the third element is the end or use, for which it is determined; the fourth element is the efficient action, done by the tool-using human (see Dessauer, 1956, and Heidegger, 1962).

Conceptions of technology differ in the way they accentuate one particular element. Authors who emphasize materiality turn technology into a separate ontological sphere of physical artifacts and the realm of "hardware" devices. Authors who stress the instrumental form tend to reduce it to a mere function in a fixed means-end relation. Those who underline the finality have to cope with problems of technological ambivalence and interpretative flexibility. Those who give prominence to "man the tool-maker" underrate the role of material agency or resistances in the subject-object relation. Every philosopher of technology who follows this strategy of sharpening gets more and more accused of being ontological, functionalist, teleological, or anthropomorphic. How should a theory of technology be constructed that avoids the fallacies of essentialism and constructivism, of objectivism and subjectivism? I shall argue for a relational and pragmatic strategy which centers around the processes of technicization and the practices to institutionalize differences by inscribing particular forms within special media.

It would produce an endless debate to dig deeper into the meaning of technology. I think it is a more sensible approach to look for how the concept of technology has been used in the history of thought (see especially Mitcham, 1994). Under my rough genealogical view a hidden agenda can be singled out. Technology has always been defined by differences in relation to something, at first to nature and life, then to culture, and now to society. In each case one assumed different ontological spheres or substantial qualities. These assumptions were confronted with more and more problems, like any ontological or substantial thinking. But even if one uses these differences as merely analytical ones, they seem to be unsuited to catch the character of contemporary technologies and the emergence of "techno-structures" in society (see Böhme, 1992, and Rammert, 1997). The first line of my argumentation begins with an exemplary critique of using substantial differences or goals in the quest for a relational approach to technology (part 2).

What kind of relation constitutes technology? Usually the instrumental relation between means and ends is stressed in the mainstream of the philosophy of technology. A more specific version relates puzzles and problems with methods of problem-solving. These conceptions presuppose that there exists a pre-fixed order of relations or that the relations are unambiguously discernible.

But the contingency and the complexity of modern technology no longer allows us to hold these assumptions. That is why some side streams in the philosophy of technology are reconstructed that prefer a process view of technology, and these views make more of a place for the fact that technologies are continuously reconstructed and have always to be enacted in concrete constellations. In the second line of my argumentation I shall prepare the ground for a turn to the procedural view of technicization and to pragmatic technology (part 3).

Which things account for differences among technologies? First, the way the relations are conceptualized makes a difference. If you imitate the style of human symbol manipulation, you will build knowledge machines of classical Artificial Intelligence; if you follow the strategy that brains use, you will design the parallel computing programs of Connectionism; if you imagine social interactions and a society of minds, you will construct the multi-agent systems of Distributed Artificial Intelligence. Secondly, the particular technology project, and how technological models are constructed and developed, make a difference. For instance, computer systems differ under the aspect that engineers or programmers prefer some techniques or traditions of design. Thirdly, the user cultures, and how computing is really practiced, make a difference. Hacking, painting, tinkering, calculating or communicating with the machine—each style of domesticating or cultivating the computer reshapes the technology by experimental practice. (See Lie and Sörensen, 1996, for the concept of "domestication," and Rammert, 1996 and 1998, for the concept of "cultural construction.")

But beyond these ways of shaping technology, there are different "stuffs" out of which technology is made. That does not mean a return to substantiality in the ontological sense. Stuff is analyzed with respect to its mediating function in relation to different practices. Technologies are considered as particular forms of practical control over input-output relations which are inscribed in the media of human activities, physical artifacts and symbolic signs. We can learn from a very general theory of media (see Heider, 1926; Innis, 1973; McLuhan, 1964; and Luhmann, 1997, pp. 190ff.) that media—or how their elements are joined—make a difference, too. In my last part, I shall plead for "a media turn" in the theory of technology; that means, particularly, to substitute the form-media relation for the means-end relation (part 4).

2. The Technological Difference: From Substance to Function

The history of thinking about technology can be seen as a continuous effort to define technology in contrast to another substance. The substances that one addressed changed, but the direction of thought remained always the same. Let me offer a brief reminder of some relevant steps in setting technological differences.

The difference between *nature* and *technology* seems to have the longest tradition. Since Greek times technology was separated from nature under the aspect that technology needs competent human intervention to come into existence, whereas nature organizes itself spontaneously. In this way, an artificial world of artifacts was distinguished from the earthly realm of nature. (Aristotle is the classical source; more recently, see Simon, 1981, and Bunge, 1985.) But the more we realize that our view of nature is also constituted by experimental intervention and with the help of artifacts, the more this defining difference disappears. The more we define the earth by the earthly limits of growth, the more we become conscious of the constructed nature of our image of nature. We fall into the circularity of a substantial definition.

The difference between *life* and *technology* follows the same strategy to define the technological difference. In this case the vibrancy and spontaneity of a living organism is compared to the crystallized body and completely regulated rhythm of a dead mechanism. (See Giedion, 1948, and

Mumford, 1967; but also Jünger, 1949, and Heidegger, 1962.) But the difference between organic life and mechanical technology is diminishing. In biotechnology, organic life is now fabricated. The genetically engineered laboratory mouse is both at the same time, a kind of spontaneous organic life and a controlled techno-structure that can be patented. In the computer sciences, mechanical models of knowledge engineering are followed up by various approaches to create Artificial Life, and to cultivate an evolutionary selection among a variety of growing programs. Machines and programs are moving beyond the purely mechanistic. Physical materiality or mechanical artificiality may be significant markers of technological objects. But they are not sufficient to encompass contemporary technology and to define its core characteristics.

A third line of distinction has been drawn between *culture* and *technology*. This culture/technology difference shows many faces. The creative realm of culture has been opposed to the accumulative realm of civilization, especially in the German tradition of Idealist philosophy. (See Dessauer, 1927, as interpreted by Mitcham, 1994, p. 31.) The meaningful sphere of language has been contrasted to the literal and formal spheres of logic and mathematics. But the late Ludwig Wittgenstein (1953) taught us that even the most rigorous symbolic technique, like mathematical logic, is based upon language games. Ethnomethodologists and conversation analysts have demonstrated that even small talk follows formal and technical rules of conversation (Schlegoff, 1972). A clear demarcation line between a cultural world of sense-making and a technological world of blind rule-following cannot any longer be maintained. The materiality of signs and the formality of rules enrich the concept of classical technology that focused on material tools, machines and mechanisms.

The difference between *society* and *technology* opens up a further line of discussion. Technological efficiency is often contrasted to the inefficiency of social institutions. The one best way of a neutral technological rationality is often confronted with the chaotic pluralism of a value-laden sociality. These distinctions are put forward by technocrats, and then reinforced by their critics (see Winner, 1977, pp. 135ff.). If we talk for instance of a technical solution of a problem, a non-social and non-political way to handle things is addressed. A line of difference is drawn between the social world and the technological order. The social way of doing something recognizes the double contingency of interaction between subjects; it requires communication, and it admits negotiation. The technical mode of making something is associated with a simple regularity of operations between objects, with programmable control and with reliable performance. In a certain way, the analytical differences between technique and praxis, work and interaction, system and life-world reproduce this division of the technological order from the social world (see Habermas, 1987). But society cannot be grasped without its technical mediation (Latour, 1994). The technologies of production (recall Marx's *Communist Manifesto*, and also see Giddens, 1990) constitute the range of economic and political opportunities of societies. The technical media of communication constitute the spatial expansion of communities and the temporal intensity of social life. They are not means from outside society, but integral parts of human association. Even social interaction, communication, and negotiation are today intensely mediated by techniques and technologies. One cannot imagine a mere political solution or social decision that is not mediated by data-processing, telephone calls, written documents, and bargaining techniques. Inversely, technology can be seen as "society made durable" (Latour, 1991). Social concepts and practices are consciously and non- consciously incorporated in the machine and inscribed in the programs. Society, too, is not outside technology; society is within the machines. A substantial difference between technology and society cannot be upheld. Material durability and reliability of performance are not limited to technology; but they enlighten the function it is constructed for.

After we have finished this quick detour through technology's history of semantic differentiation, we can draw some conclusions. If technology can be defined sufficiently neither by its artificial status nor by its materiality, nor by its mechanical character nor by its non-social character as neutral means, then all substantial differences can be deconstructed and one should give up this strategy of definition. If technology can be observed in each of the above mentioned worlds, then we should look for a particular function that technology performs across the substantial differences. If we cannot presuppose a world of clear-cut ontological spheres, we are forced to construct relational concepts that have to be tested. The search for a useful relational concept of technology should start with a short review of some philosophies which have emphasized the relational form, the process and the performance of technology.

3. Technicization and Technical Practice: Relations That Constitute Technology

If we mark the materiality, the artificiality, and the instrumentality of technology, we have not grasped the very idea of technology. Technology does not exist only as a material ensemble, human-made artifacts, or as a means-end relation. It is a particular relation to the world that constitutes technology. What kind may this relation be?

Ernst Cassirer has proposed that we look at the process of becoming, the "forma formans" of technique, not only at the structure of being, the "forma formata," of the technological ensemble ([1930] 1985, p. 43). He discovered a relationship between the function of language and the function of technology. Both serve to grasp reality by constructing it. Language constructs communicative reality by means of theoretical thinking; technology constructs material reality by effective means. In magical techniques both forms of meaningful practice were still intertwined. It is the particular idea of *causal relations and necessary connections* that makes modern technologies differ from magical techniques as well as from aesthetic artifacts. From this time on, the process of technology- making included instrumental abstraction from other meanings and connotations, the objectification of the world, and the encapsulation of intended effects from non-intended ones in a black box.

In his late work, *The Crisis of European Sciences*, Edmund Husserl developed a strongly critical attitude towards modern science and technology. He diagnosed a great divide between a physicalist objectivism and a transcendental subjectivism. In reconstructing modern mathematics and the technical use of formulae in the sciences he comes to the conclusion that the process that he calls *Technisierung* ([1936] 1982, pp. 49 ff.) is the central cause of the divide and of the consequent crises of modernity. I translate this term as "technicization." Technicization connotes the narrowing of experience by abstraction from other meanings, simplifying moves to methods instead of deep sense-making, and following empty rules instead of full understanding. This pathological form of technicization turns reality into a resource for possible worlds. According to the late Husserl, the form of technicization achieves an increase of efficiency at the price of a loss of meaningfulness. In his sympathetic critique, Hans Blumenberg reminds us of the necessary ambivalence of technicization: there could be no creation of new worlds without the risk of alienation from the life-world. He blames Husserl, because he does not see the paradox that even phenomenology as a method of thinking is itself a part of technicization. Like the modern sciences, it raises the consciousness of the contingency of the world (Blumenberg [1963] 1981, p. 47).

At this point, we can define *technicization* as a schematic relation between causes and effects that operates independently from the communication of meaning. The schematized elements can be coupled and combined into complex technical systems. A mathematical engine or algorithm consists of some counting formula and formal instructions, so that even complex problems can be computed without knowing the context; a mechanical machine connects a couple of tools and it prints my text precisely without reflecting on its moral implications; a skilled sharpshooter combines perceptual and bodily techniques so that he may kill a person on command without weighing the pros and cons. The difference between an algorithm, a machine, and a human being does not matter on this level. This will be the subject of the last part, where I shall talk about the media that make differences. What matters here is the difference between *the technicized and non- technicized* relations. In my view it is a *gradual* difference, not a substantial one. Technicization means more reliability, tighter coupling of elements, less dependency on contexts, and more efficiency of control. Techniques to attain technicized relations are the simplification and specification of complex causal relationships by separating, purifying, and schematizing the elements, the fixing of the relations by repetition in time or incorporation in matter, and the closure of a system by encapsulation and "black boxing."

Can we say something more about the relation that constitutes technology? Perhaps we can use some ideas of the American philosopher of technology, Don Ihde, who has read Martin Heidegger as a scholar of phenomenology and who is also under the influence of pragmatism (Ihde, 1979 and 1983). In his book, *Technology and the Lifeworld* (1990), he focuses on human-technology relations and the cultural embeddedness of technologies. Following a relativistic ontology he draws a distinction between the "direct bodily and perceptual experiences of others and the immediate environment" and "technologically mediated experiences" (Ihde, 1990, pp. 15 ff.). And he suggests—as I proposed above—that we look for different degrees of mediation in our technologically textured world.

The position that conceives of technology as instruments to transform something can be blamed as a Cartesian and subjectivist bias. It is supposed that a self or a subject can use a thing as an instrument to effect something in the outer world. But is it reasonable to speak of a subject, if the technological instruments change the status of subjectivity? Who is the subject in an atomic plant? The clear- cut limits between subject and object become disturbed. "Technics is a symbiosis of artifact and user within a human action" (Ihde, 1990, p. 73). The material relation between humans and the world should be conceived as a *symbiotic and mediated* relation instead of as a divided and instrumental one.

An objectivist bias emerges, if the means-end relation is criticized because of its perversion. Supporters of the technocratic position as well as critics of our civilization—from the left and the right—tend to stress the strength of the technological imperative. They both point to means that become an end in themselves. The first welcome this technological preference as a means to rationalize a capitalist economy and society (see, e.g., Taylor, 1947; Veblen, 1954). The critics of contemporary culture complain about the totality of the technological order, alienation, or even the disappearance of the human project (see, e.g., Ellul, 1964). But is it reasonable to think of technics (Winner, 1977) as completely out of control? It is the same divide between subject and object that leads to such an objectivistic and deterministic view. I propose to take seriously these observations of technology's alterity, but to transform them into "alterity relations" (Ihde, 1990, p. 98) with different intensities and grades of agency. Following a mediation view, agency can be seen as distributed between *humans and non-humans* (compare Latour, 1988). Agency is not reserved to human subjects; but humans are the only agents who can experience and reflect this relation. They cannot reflect the relations from outside with a satellite view, but they must do it amidst them, with a navigational view.

A third fallacy concerns *hermeneutic relations*. In this case, the fallacies of functionalism and of intentionalism have to be avoided. A follower of functionalism sees no difficulties in detecting the meaning of a technology. One could say: Function constitutes technological form; or, with the words of the Bauhaus philosophy: Form follows function. An intentionalist thinker would search for the particular aims a technological artifact was designed for. But it is rather difficult if not impossible either to reduce an artifact to one general function or to interpret an artifact's particular meaning. Should we look for the inventor's vision or should we review the engineering and marketing plans of the producer or should we observe and ask the users of technology? Daniel Dennett (1989)—reflecting on the interpretation of texts, people, and other artifacts—destroys any hope we might have to find a definitive and final interpretation of a technology's function. We have to look, with him, for a pragmatic solution of these problems.

John Dewey (1916, 1925) has developed a philosophy of praxis that denies such things as functions and intentions and that rejects the rigid subject- object divide (see Hickman, 1990, and Hood, 1982 and 1992). Technology and its use cannot be divided from one another. Technology is defined as an "active productive skill" (Hickman, 1990, p. 18). It encompasses all means which are used in the concrete process of experience to control changes that interfere between the beginning and the end of a process. Technology has no existence and function outside of its use. It is what I would like to call the *use-relations* that create both the handled object as a tool and the manipulating gesture as technical practice (see Flusser, 1991). A technical object differs from a non-technical object insofar as technology includes a pre-structured interrelation between objects and operations as a self-defining feature. Technology *is* this relation, which I would like to call *interobjectivity*. This interrelationship is revealed in the technical practice and its use-relations. It is based neither on the properties of the related things nor on the intention of the active humans alone. Neither the relation of the upcurrent and the shape of wings nor the volition to turn them into tools of flying constitute the technology of the airplane. The art of flying comes up only in the interplay of active productive experiences, like inquiry, tinkering, and experimenting, and the relations between the objects that are thereby produced as schemata of design, preferred combinations of materials, and rules of piloting.

Andrew Pickering (1995) has found a metaphor to describe this process: "the mangle of praxis." With this metaphor he points out that the objects and their respective relations are changed by the inquiring practice. But also the intentions of the human experimenter are dissolved into a sequence of step-by-step accommodated intentions, when they come into contact with the resistance of the objects and the structure of their relations. This pragmatic conception differs from the materialistic notion that the objective physical properties or the laws of nature limit the technological projects and the range of technological possibilities. The experience of limitation is dependent on the particular interrelation between objects and on the specific intention they are approached with. Experiments do not fail and technologies do not function because some objective material conditions are missed or violated. Functioning technologies have to be actively produced, seeking different constellations between objects and adapting technological intentions. The knowledge of the right formula, of the effective functional organization, and of the physical properties is not sufficient to build a technology. Practical experience is needed. In his study of the reconstruction of experimental laser devices, Harry M. Collins (1992) has demonstrated that both embodied experience and its enactment by at least one member of the original team were necessary to reconstruct the device at other places with success. To attain an objectified and functioning technology, ultimately, you need more than the plans for its construction and more than the mixture of materials. You need the experience about how to tune the relations between the objects and the projects, and you need the experience of what is possible and what can be actualized in which way and with which effect. As in a "dance of agency" (Pickering, 1995, p. 21), efficient relations of interobjectivity come up. Only later on do they become fixed in a formula and interpreted by a simplified schema of causes and effects.

New technologies are constituted by a further type of relations which I call *evaluative*. Technologies are, from the beginning on, related to other technologies; e.g., relations of competition with newer ones, or relations of compatibility with established ones. They are not the singular incorporation of one idea out of an indefinite realm of technical ideas, which is often what is supposed by philosophies of invention (see Dessauer, 1956). They are neither related to one another by a functional logic of organ substitution which governs the successive substitution of one function of the human circle of activities (*Handlungskreis*) by the next one, starting with the energetic function of muscles and ending with the steering function of the brain. That is the way anthropological theories of technology like to conceive the relation (see Kapp, [1877] 1978; Gehlen, [1957] 1980). Nor can the technologies be unambiguously positioned in a ranking related to technological or economic efficiency. This is a practice that is preferred by historical, economic, and social theories of technical change. (See Elster, 1983, for a critique of traditional Marxist theories; for empirical deconstructions, see Bijker, Hughes, and Pinch, 1987; Dierkes and Hoffmann, 1992; and Cronberg and Sörensen, 1995.) Technological innovations cannot simply be explained by rational economic choices or by criteria of higher technological efficiency. They are characterized by a relation of "creative destruction," as Joseph Schumpeter called it (1942). Universal and substantial criteria of technological superiority can definitely not be indicated. The multitude and mixture of criteria do not provide a sound basis for the evaluation. The heterogeneous and historical character of criteria sets do not admit a neutral and universal procedure.

That is why I propose another relational concept that may handle the difference between established, highly evaluated technologies and profane, non- evaluated technologies. It is the concept of "the technological archive." Boris Groys (1992, 1997) has transferred the concept of the "archive" from Michel Foucault (1973) and Jacques Derrida (1995) to describe the mechanism of innovation in the fine arts and later on in the useful arts of technology. It can be doubted that there exists either any conclusive argumentation to decide on the aesthetic superiority of a piece of art or any universal and rational procedure to determine the functional superiority of a piece of technology. The existence of any substantial criteria is called into question. It can be named a paradox of innovation to refer to the established rules of the game and at the same time to break them and to elevate previously lowly rated features to now highly evaluated criteria, as Richard Wagner did in "Die Meistersinger von Nürnberg." In the arts, collections or museums are considered a mechanism to handle this paradox. In the beginning the African art of mask-making and the practice of cubist painting inspired by it and invented by Pablo Picasso and Fernand Braques was labeled primitive. But later on, when after a time of fermentation these pieces of art were acquired by art collectors and museums, they became the highly evaluated masterpieces of cubism and modern art. The mechanism of the archive turns primitive and profane practices and even the practice of anti-art into art which is socially accepted and highly rated. It is just this mechanism of the archive that constitutes a formal exchange relation between the profane sphere and the chosen realm of artifacts. Even in times of post-modernity, with its loss of certainty and universally shared values, this mechanism guarantees the continuity of innovation, but not substantial progress.

This relational approach can be transferred to technological innovation. Following John Dewey's pragmatic-technology conception, one can observe a huge mass of profane technical practices which are only locally significant and pass quickly. But these practices are elevated into the status of socially acknowledged and highly evaluated technology when they get exhibited at inventors' and industrial fairs; when they receive recognition by publication and in the education of engineering students; when they get successfully patented, and when their products are diffused via mass production. I subsume under the "technological archive" all those technical practices and their products that are officially included in the "state-of-the-art" in a technological field. This can happen via publication, collection, codification, and other practices of institutionalization. Legitimate technologies are divided from illegitimate ones, safe technologies from unsafe ones, efficient technologies from inefficient ones. Technologies in societies are also constituted by these evaluative relations.

To *sum up* the considerations of this part: the view of technology is changed from a substantial to a relational perspective. In a first step, I changed the emphasis, with the help of Ernst Cassirer, from the material ensemble of artifacts to the process of technicization. In a second step, I corrected Edmund Husserl's critical view of disembedded technicization with Hans Blumenberg and pleaded for an ambivalent and gradual concept that recognizes differences between more and less technicized relations. In a third step, I redefined the subjectivist view of instrumentality and the objectivist view of the perverted means-end relation, inspired by Don Ihde's pragmato-phenomenological interpretation of Martin Heidegger's philosophy of technology: a symbiotic and mediational view was substituted for the subject-object divide. In a fourth step, John Dewey's pragmatism helped to reject the merely functional and the merely intentional interpretation of technology. Practical relations constitute the meaning of a technology; neither technological options nor technological visions can do this. At the end, I argued that all approaches failed which used substantial criteria to evaluate technologies in comparison with one another. I took over the concept of the archive—developed by Michel Foucault and described as a formal mechanism by Boris Groys—to demonstrate how one technical practice is institutionalized compared with another one. It is just the inclusion of a profane technical practice in the highly evaluated collection of the state-of-the-art that turns it into a relevant and legitimate technology in society.

I have identified three types of relations that constitute a technology: causal, hermeneutic, and evaluative relations. Causal relations consist of agents and objects that are "mangled" in tightly coupled effective systems. Hermeneutic relations emerge with use, and they determine the very meaning of a technology by the way it is really practiced and not how it was originally projected. Evaluative relations connect different technical practices and artifacts with one another and regulate how they get included in the social collection of legitimate technologies and how this techno-structure gains influence. Altogether these relations constitute the particular form of technicization that is practiced and institutionalized in social life.

Up to now I have not answered the question about what these relations are made of. Usually, one conceives of technology as "hardware," as made of physical objects. I kept this question open intentionally. I did not want to narrow the wide process concept of technology too early. After the constituting relations have been presented, I can finally turn to questions about what stuff technology is made of and what are the differences.

4. The Difference of Media: The Stuff Technology Is Made of:

I have characterized technology as a certain form of practice. So it is obvious that stuff is needed that can be formed. Even in the framework of the instrumental view of technology, it is important whether an instrument is made of wood, iron, or plastic. We can learn from media theory (see Heider, 1926, and McLuhan, 1968) that the stuff should have two particular features. It must be permeable and malleable, so that it can be shaped easily. It must be hard and durable, so that the shape is clearly discernible and constantly repeatable at any time and at any place. It is the stuff's capacity to function as mediator in the technical process, not its trivial material differences that I want to address. A *medium* can very generally be characterized as a stuff that smoothly lends its material characteristics to be shaped and that minimizes its resistance, on the one side, and that gives shapes its distinctive and visible expression, and that does not disturb by its own features. Fine-grained sand easily allows us to build walls or to inscribe signs, but these artifacts show no hardness and durability. Therefore sand is a bad mediator for constructing buildings in comparison to cement or for inscribing signs in comparison to wax and paper or even the electronic display of my computer.

The category of media is used here very broadly. It is not restricted to the media of communication. If a stuff is so fine-grained and loosely-coupled that it disappears in the background of our experience, and if the stuff makes it possible to build tightly-coupled relations between elements, like stones or signs, then we speak of a medium. To be a medium is not a substantial feature, but it depends on the context of use whether a stuff takes over a mediating function. We can now ask precisely for the differences that media make in our context of technical practice and technicization. Following a broad stream of thinking (e.g., Popper's three worlds, 1972) I will relate to three types of stuff:

—first, *human bodies*, including action and perception, usually seen as the stuff the interactive or social world is made of;

—second, *physical things*, including physical and biological stuff, elements and processes that constitute the interobjective or natural world;

—third, *symbolic signs*, including letters, numbers, and icons, the stuff the intersubjective or cultural world is constructed of.

My view deviates from the mainstream of theoretical approaches in two ways. It includes techniques of action and techniques of perception. I cannot merely count on the broad conception of technology in pragmatism and phenomenology. My view can also be based on research in anthropology, which has observed a strong interdependency between action, bodies, and technology (see Mauss, 1936). Additionally, my concept integrates symbolic technologies from the first cave paintings up to the last version of virtual reality in cyberspace. In this case, too, I can refer to witnesses who have stressed the co-evolution of hand and word (see Leroi-Gourhan, 1980), or who have emphasized the equal importance of mechanical and media revolutions (see Innis, 1951; McLuhan, 1968; Luhmann, 1989).

Technology emerges only if three conditions are fulfilled. A use relation has to be found or created between a bodily experience and an outer environment that is mediated by something. A relation of interobjectivity has to be established between two elements that assures an expectable and tightly-coupled output from an input. There must be a memory or an archive that marks and fixes the evaluated relations in a way that can be repeated often and reproduced in any context. Human bodies, physical matter, and symbolic signs are all together required to constitute technology. A machine without someone who controls it is no machine, but an exhibit in a museum or junk in the scrap-yard. A technique to crush nuts with a stone or a technique to use plants to heal wounds which is not marked and made durable by an instrument or by a significant formula gets lost and remains an incident in animal or primitive life (see Strum and Latour, 1987). But I shall treat the three types of stuff separately in order to inquire about their particular mediating functions.

Human bodies can be used as media to inscribe a technical form when they can be managed so as to behave in a fixed and repetitious manner according to an effective schema. Movements can be schematized and drilled. Sensations can be coded and ritualized. The finer-grained the units can be and the stronger the lines between them, the more they get technicized. Military drill, Taylor's methods to simplify work movements, and routines of machine operation can be counted within this type of technology of action. They are based on repetition and training the body in order to delete consciousness. But the acting bodies lose their mediating function if humans become too aware. Here we can better see the ambivalence of technologies that are made of human bodies.

They are imperfect technologies, because human actions cannot be fixed and linked with the same reliability as physical things; but they are at the same time highly flexible if situations change and problems come up. This type of technicization, that uses the medium of human action, may be called *habituation*. With this notion I refer to concepts of habit-formation (Gehlen, 1980, Berger and Luckmann, 1967) and of routine action (Giddens, 1984).

Physical things and processes are the most successful stuff to serve as a medium to make technical forms durable and transferable. Fine-cut work routines and communication functions can be mimicked by mechanical operation. New effects of interobjective relations can be discovered and isolated. These techno- facts build the huge stock of the technological archive. They can be combined and assembled to build large and very complex technological systems; for example, a mechanized system of car production is composed of power, work, transport, and controlling machines; or the network of electric power supply consists of turbines, dynamos, transformers, and cables. These material technologies range from simple tools to assembled machines, from closed technical systems to open technological networks. See for this typology Tushman and Rosenkopf (1992). Ultimately, I use the broader concept of technological systems that includes human operators and symbolic artifacts (see Hughes, 1987, and Perrow, 1984). But my analytical concept differs from their concepts insofar as I emphasize the media that make the differences. This hardware type of technology is predominant in theoretical discussions, because it is so obviously present as a resource and as a constraint of action. Physical materiality means a gain in durability and calculable substitutability—think of the thousands of compatible parts a car is made of—but a loss in flexibility and reversibility: think of the difficulty in changing the production line or even the whole trajectory of cars with internal combustion engines. This type of technicization that uses the medium of physical operations and processes may be called *mechanization*.

Signs are a special stuff. They constitute a third realm between the two other worlds. (See, for a tripartite concept of meaning which distinguishes among signs, interpretants, and objects, the works of Peirce; see, for an interpretation from the perspective of social pragmatism, Wiley, 1994.) Materiality and human practice are required when signs come into existence. But sign systems, like the alphabet or arithmetic, can be completely separated from the behavioral and physical contexts from which they emerged. They can be precisely manipulated by following procedural rules. Calculation techniques, chemical formulas, and computer programs belong to this category of symbolic or software technologies. The formal character of algorithms enables us to transform sign and rule systems into "trivial machines." In combination with a computer they open the door to the simulation of any given technology. (See the works of the inventor of the "universal" and "intelligent" machine, Turing, 1937, 1950; and, for relations between machine-like human actions and computable operations, see Collins, 1990.) To use signs as a medium of technicization means the highest precision of coupling and no wear and tear in comparison to physical machines. But it calls also for great efforts to make inputs and outputs compatible with the environment. This type of technicization, that uses the medium of signs, may be called *algorithmization*.

5. Features and Preferences of a Social Pragmatic Concept of Technology

What is the use of this pragmatic and mediational concept of technology? Generally, we can observe more differences between technologies; we can construct a more detailed analytical tool-box; and especially we get a fresh view of the differences that constitute technology. At the close of my contribution I summarize my considerations with regard to some advantages.

At first, I developed technology as a particularform that makes a difference. *The technological* *form schematizes, links, and fixes objects, symbols, and agents so that a useful effect can be repeatedly expected and intentionally controlled.* Technology is no longer defined by essential distinctions: from nature, culture, or society. The technological form is defined across these lines of distinction. It distinguishes the technicized form from the non-technicized. It makes a distinction between the tightly-linked and the loosely-linked form. It stresses the difference between mediated and direct experience. This gradual concept of technicization is more suitable for empirical studies than others. It especially allows us to analyze the processes of becoming a technology or of losing the character of a technology. One can use it to identify different degrees of technicization and their social implications.

Secondly, I spelled out *three relations* that constitute technology: use- relations, causal relations between objects, and the evaluative relations of the archive. *Use-relations* define the technology's meaning, independently from the inventor's vision or the producer's design. This pragmatic concept helps us to avoid false generalizations from modern or western types of technologies. It is always technology-in-use and technology-in-a-situation that we experience. The *causal relations* or the fixed relations between input and expected output concern the interrelations of objects that I called interobjectivity. This relation limits the idealist view, but also the approach of radical constructivism that "anything goes," or that technology can be entirely socially shaped. And it also qualifies the notion of material causes, taking materiality as timely-emergent resistance against certain practices of human intervention. The *evaluative relations* of the technological archive are the mechanism to establish the state-of-the-art within technological fields. They allow us to explain technological innovation without supposing some substantial quality or neutral efficiency criteria. This relational and pragmatic concept of technology allows us to capture the contingency and ambivalence of technologies without losing rigor. For this concept is sensitive to different cultural practices and local situations.

Beyond the form in which technology is schematized, and beyond the relations that define technology, I identified a *difference of media*. It makes a difference whether human bodies or physical matter or symbolic signs are the media that the forms shape or are inscribed in. This *media-form relation* seems to open up more opportunities to analyze the new information technologies and biotechnology than the traditional means-end concept. With its help, the classical machine concept of transformation, and the cybernetic system concept of communication may be combined. It may be of great use when we start to analyze the techno-structures of the coming knowledge and network society and ask where technical and human agency are situated and how it is distributed in our technologically mediated social life.

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