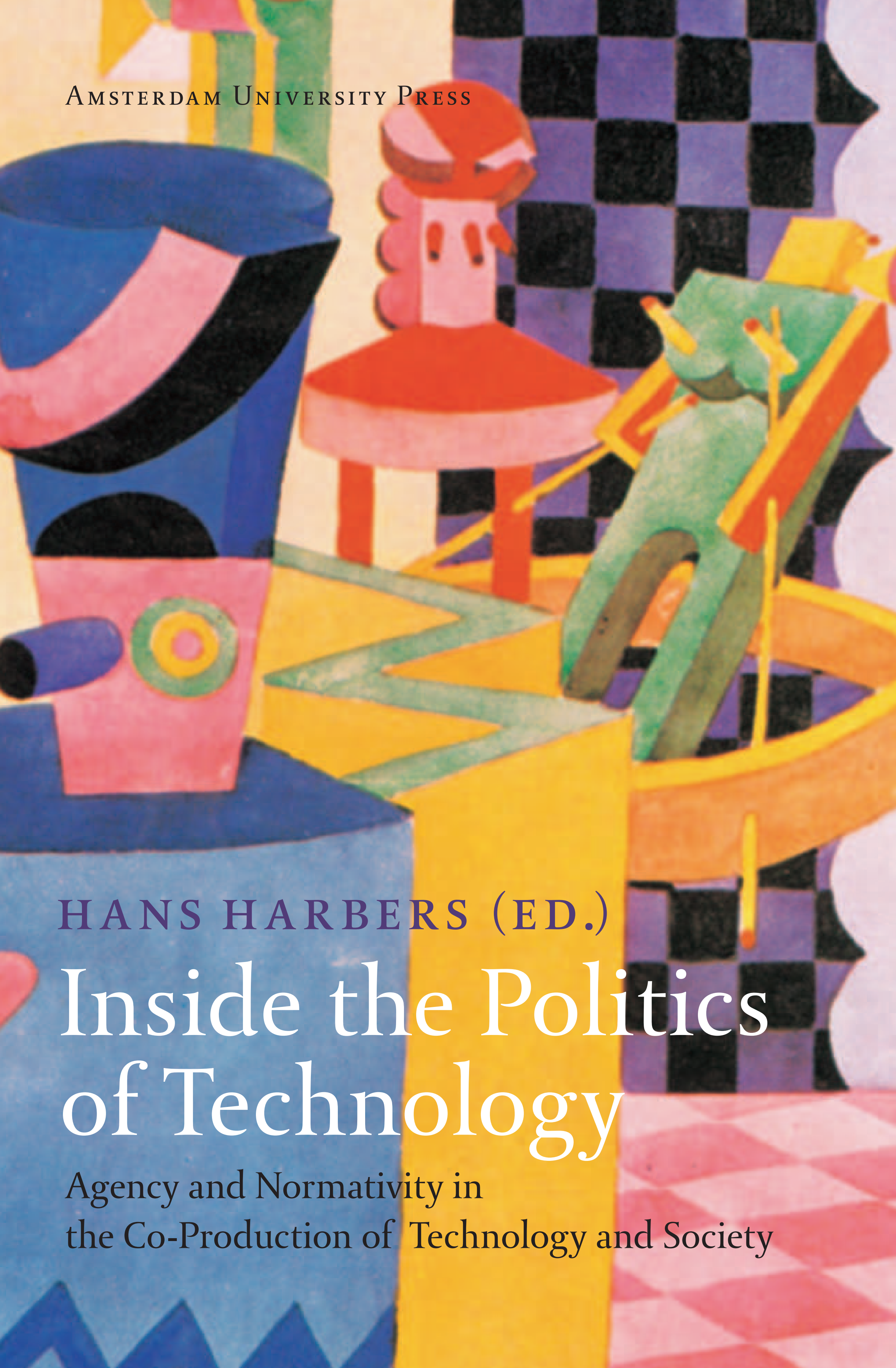

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HANS HARBERS (ED.)

# Inside the Politics of Technology

## Agency and Normativity in the Co-Production of Technology and Society

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**Hans Harbers (ed.)**

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## The Politics of Agency

# Preface

During a stay from 1998-2000 as research fellow at the University of Twente, Enschede, the Netherlands, I participated in the so-called "Mumford-program" – a project to stimulate and co-ordinate intellectual collaboration on the spot between various strands of Science and Technology Studies: from philosophy, sociology, and history of science and technology up to research policy and management studies. This volume, discussing the analytical and normative consequences of (conceiving) technology and technological artifacts as agents, is one of the project's principal results. Accordingly, the contributing authors are (or were) all engaged with the University of Twente.

Earlier versions of the contributions to this volume were extensively discussed in a common workshop with Emilie Gomart and Knut Sørensen as external discussants. I would like to thank both of them for their stimulating comments and critical remarks. In addition, different chapters were reviewed seperately by experts: Donald MacKenzie (Back to the Drawing Board), David Hess (Artifacts as Social Agents), Adele Clarke (Diversity and Distributed Agency in the Design and Use of Medical Video-Communication Technologies), Annemarie Mol (Choices and Choosing in Cancer Genetics), Andrew Feenberg (Artifacts and Attachment), Sven Kesselring (Taking the Socio-Technical Seriously), Bryan Wynne (Trapped in the Duality of Structure), and John Law (The Cultural Politics of Prenatal Screening). We are grateful for their encouraging remarks and helpful criticisms, which improved the original drafts substantially. Dick Pels, Tsjalling Swierstra, and Nil Disco commented on the earlier versions of the introduction and the epilogue. Their persistent support helped me overcome moments of hesitation.

Finally, I would like to thank George Hall and Nil Disco for their careful corrections of the English, and Maarten Zeehandelaar for his conscientious compilation of the index.

Groningen, June 2005
Hans Harbers

# Introduction
# Co-Production, Agency, and Normativity

*Hans Harbers*

The Netherlands, 9.50 a.m., 11 February 1992: A few minutes after take-off from the nearby Twente Air Force Base, an F-16 fighter plane gets into trouble, tries to turn around and return to the base, but crashes into the residential area of Hasseler Es in the town of Hengelo. Houses catch fire, cars are destroyed, summerhouses and sheds are ruined. Total material damage: € 1 million. Plus an F-16 of course – a multiple of that amount. Fortunately, there were no personal injuries; even the pilot was saved by his ejection seat at the last minute. A "divine miracle", according to Hengelo's mayor, Lemstra.

The accident prompted an immediate debate on the risks of military flights over densely populated areas. Voices were raised demanding to closure the Twente Air Force base. Part of the discussion concerned the cause of the accident. Was the engine failure caused by a technical defect, fuel problems, or could it simply be a matter of a bird flying into the intake compressor? And what about the pilot? Did he act properly? Shouldn't he have flown straight ahead after he had received the first signals of engine trouble from his dashboard instruments, instead of making a sharp turn to the right in order to return to the base as soon as possible, a move which brought him above the stricken area? Or, simply another possibility, might not the accident have been caused by the lack of radar control, since that very morning the ground station was out of order due to technical maintenance?

This was the twenty-fifth F-16 to crash since this aircraft was first deployed by the Dutch armed forces in 1979. According to the Air Force's public relations department, 40% of these crashes were attributable to technical troubles; 60% to human failure. But what is technical and what is human in this case? Is the absence of ground radar, due to maintenance work, a technical or a human affair? If, as it appears, engines can be destroyed by flying birds, why can't human beings take that into account? And when the engine fails, this is manifested to the flying pilot as a technical defect, but couldn't it have been foreseen by maintenance personnel at the airbase, thus making them or their military superiors accountable? If something went wrong during the engine production process, shouldn't General Dynamics, the manufacturer, be held liable? Or does the final responsibility lie with the politicians who decided to purchase the F-16s? Apparently, technical issues cannot be neatly distinguished from human actions. We are confronted here with a hybrid situation in which human beings and technology are tightly interwoven – a mixture, a muddle of man and machine.

This is all the more obvious when the attribution of guilt commences from the other side – human error instead of technical defects. Suppose the pilot makes a mistake: is it his fault, or just the consequence of the sophisticated technology he has to deal with? In his cockpit filled with instruments and onboard computers, he receives an amount of information that, according to experts at an air force conference in 1988, threatens to exceed the processing capacity of human beings. Moreover, scientific research shows that the high speed of an F-16, in combination with its vast manoeuvreability, can result in sensorial disorientation: human brains do not always function in accordance with normal physiological processes under such extreme conditions. Consequently, it is not avoidable human failure that is at stake here, but the inevitable, natural limits of (the body of) the human being. These limits are reached or even surpassed by technological developments, which, in turn, paradoxically enough, are initiated by those very human beings. Where does one draw the line between man and machine, between human responsibility and technical inevitability, between the subjective world of politics, culture and morality and the objective world of science, technology and nature? There is no such line – at least not *a priori* – stored in the nature of things, as an essence. This line is drawn only in retrospect, step by step, every time the story is retold. Each new reconstruction of the crash is another improved attempt to clear up the muddle.

It was eventually proven that the pilot acted as capably as possible, so he was not to blame. But that only partly settled the question. After this first clarification, however important it was to the pilot, the accident could still be ascribed either to human error, e.g., false instructions from the control tower, poor maintenance, or lack of knowledge about the migration cory patterns of birds, or, alternatively, to technical deficiencies, e.g., fuel problems or engine failure. In the end, a year after the crash, an official research report established the "real" cause of the crash: the snapping-off of a 10-cm metal pin that regulated the position of a fin in one of the 13 cogs in the rotor of the F-16. This set off a chain reaction demolishing the cogs one by one, ending up in a complete breakdown of the engine. But even then the problem of humanity versus technology was not solved. Who could be blamed for this technical defect:

service engineers, the Air Force, or the manufacturer? The latter was ultimately left holding the bag. But still then, was it a production fault or a designer's error? Again, different actors and different technicalities are involved.

Apparently, a definitive dividing line between technical and human causes cannot be drawn. However technical the cause of the crash appeared to be, human beings always come along with the technicalities – and vice versa. Purely technical causes are just as illusory as purely human faults. Nevertheless, this distinction played a prominent role in the unfolding process of attribution and denial of guilt. It was that very distinction, used by the various actors, or more precisely, human actors, that enabled them to vindicate themselves one by one and step by step – first the pilot, then the control tower crew, subsequently the maintenance personnel, etc. So, on the one hand, we have a knot of socio-technical relations and interdependences that cannot be disentangled. On the other hand, this is exactly what is done in successive reconstructions of the disaster: the knot is unravelled in order to attribute crime and punishment unambiguously.

## Issues

In a nutshell, this story about the crash of a military aircraft, the subsequent friction about its human or technical causes, and the related distribution of accountability illustrates the three central issues of this book. First, we have the *co-production* of science, technology and society where humanity and technology are mutually dependent. Second, the problem of *agency* – who are the principal agents in this process of co-production: individual human beings, social institutions and organisations, or even nonhuman agents like machines and technological artifacts? Can the latter be charged with capacities and competencies for acting? And what then do we mean after all by action and agency? Third, the problem of *normativity*. As the story of the F-16 illustrates, the quest of agency immediately refers to normative categories such as liability, accountability, and the attribution and distribution of responsibilities: what or who is responsible for whom or what? And what are the political consequences?

Let us briefly review these three issues, while at the same time providing a description of the context of the contributions to this volume.

## *Co-production*

To say that science and technology play a decisive role in our society has become commonplace. It is often said that we live in a "knowledge society" or in a "technological culture". That is, scientific knowledge and technological artifacts are part and parcel of our way of life. Without a properly functioning electricity network there is no social cohesion; television and other communication techniques have become conditions for citizenship in a media democracy; and developments in biomedical sciences and technologies are constitutive for the way we define health and disease, or even life and death; etc. But how to analyse and evaluate this "world making" capacity of science and technology (Goodman 1978)? Traditionally, two contradictory stories set the stage: an optimistic and a pessimistic one.

The first story is one of hope – the hope for the control of nature, for the emancipation of mankind, for rationality and instrumentality. This is the story of progress – in science and technology and thus in society. In such a "scientistic" world view, both natural and social relations can be known and controlled. Technical engineering supplemented by social engineering – here is the Enlightenment's ultimate Dream of Reason, of human freedom by controling physical and social nature, of humans as the measure of all things.

This utopian and rationalist story of hope is always accompanied by a much more dystopian and romantic story of despair – despair about the loss of the subject, about the decline of humanity, authenticity, and naturalness. In this second story, told by traditional philosophers of technology like Ellul, Heidegger and Jonas, science and technology pop up as totalitarian threats to an often implicit and idealised *condition humaine.* It is the story of being over run by a technological juggernaut, which is guided only by instrumental values and system requirements. In this view, human freedom is not realised through the pursuit of science and technology; on the contrary, here freedom is annihilated by the rational-technological-instrumental imperative.

Both stories are still endemic at all kinds of societal levels – common sense, fiction, policy prose, and so on. And they still nourish many contributions to public and political debates about the social impact of technological developments. Yet there are good reasons to dismiss both these scenarios. First, they are too general, on the one hand, portraying science and technology as a homogeneous unity lacking internal differentiations and uncertainties; and on the other hand, portraying society or humanity as a monolithic given bereft of cultural pluralism, power differences, and historical changes. Second, both stories deny the double bond, as Beck (1992) has called it, between science, technology and society. Acknowledging the pessimists' position that many social problems nowadays result from developments in science and technology, at the same time we are thrown back upon scientific research and technological developments to solve these problems. We may assume that there would never have been a hole in the ozone layer without science and technology, but we can hardly expect to seal it without mobilising scientific knowledge and technological innovations. Third, both stories treat science and technology as a black box, i.e., as an independent variable that explains social developments, for better or worse, but in itself not in need of further analysis.

In an effort to avoid these shortcomings, contemporary science and technology studies (STS) dissociates itself from both of these scenarios. By opening the black box, these studies unravel in detail the interactions and the mutual constitution of science, technology and society. How is science and technology produced, and under which social conditions? What are we doing with scientific knowledge and technological artifacts? But also: what are science and technology doing with us? These are leading questions engendered in the idea of *co-production,* a basic article of faith within STS.[1] Science and technology, according to this notion, are not external determinants of social order; but neither is the opposite the case, that social structures can explain scientific and technological developments without further ado. No clear distinction can and should be made here between *explanans* and *explanandum.* Neither science and technology on the one hand, nor society on the other, are transparent entities with a monopoly on explanatory force, in whatever direction. On the contrary, they are, to paraphrase Wittgenstein (1953), "internally related", that is, mutually constituted in one and the same historical process.

Accordingly, within STS, alleged essences of science and technology, such as objectivity, neutrality, and efficiency, are replaced by empirical historical and sociological studies of the construction of practices flying these colours. Universality bows to contextuality. Explanations of order give way to stories about processes. Utopian or dystopian blueprints are abandoned in favour of practical learning processes. This empirical and pragmatic turn in the study of science, technology and society pays off, compared with the hermetic pessimism of traditional philosophers of technology or the naive optimism of their intellectual antipodes. It enables detailed research into the hybrids of socio-technical relations and gives scope to practical policies, informed by this research and geared to local situations.

But having formulated this common sense within science and technology studies, and the point of departure for this volume, a series of questions now present themselves. For example, how actually to conceptualise co-production, and how to study it empirically? Several notions have been proposed, generating different viewpoints.[2] Moreover, patterns of co-production can be analysed on several levels: on the micro-level of single artifacts;[3] on the meso-level of technological regimes, which focusses on institutions, standards, and other kinds of congealed practices; and on the macro- and long-term level of socio-technical landscapes, e.g., by studying moving junctions in the seamless web of science, technology and society, or by analysing the role of technology in the preservation – and deterioration – of social cohesion. The object of research also varies along with these different concepts and levels – from structures and institutions, social groups and individual agents, through cognitive entities like ideas, theories, and concepts, to artifacts as actors in the process of co-production. In short, within STS, co-production is a communally sanctioned notion, useful in the fight against ancient enemies, but nonetheless, contested as soon as it descends to earth in the form of concrete analyses and inquiries. Various contributions to this volume address this first issue.

### *Agency*

These different interpretations of the notion of co-production are linked to different answers to the question of who in fact acts in this process of co-production, and – one step further – what is actually meant by action and *agency*? Surely, individual human beings are principal agents in the co-production of science, technology and society. But who is included, and who is excluded? Distinctions between experts and laymen, designers and users of technology, or scientists and politicians become relevant in this context. Who is empowered to act, and who is not? And what are the consequences of these differences in agency for the attribution and distribution of guilt, esteem and responsibility? Can actors be held responsible for actions they are not, or only marginally, involved in? In other words, is social agency a precondition for moral agency?

Such questions become all the more urgent when we consider not only individual human beings as principal agents, but also include social organisations and institutions. Obviously, these play an important role in the co-production of science, technology and society: professional organisations, economic and legal institutions, political movements, public and private companies, consumer and patient organisations, etc. All these are relevant players in the field. But do they act in the same way as individuals, and can we hold them responsible in the same way as individual actors? These questions relate to the traditional sociological issue of agency and structure, of aims and unintended consequences. Are social change and stability the outcome of conscious, intended actions, or merely blind processes, occurring behind the backs of the people involved?[4]

The problem of agency becomes even more complex if we also consider the possibility of nonhuman agency. Knowledge and methods, technological systems and artifacts, standards and regulations – they all act or at least enable the action of others. Within the field of science and technology studies, Actor-Network Theory (ANT) has drawn special attention to these "nonhuman actors".[5] The core of this theory is the principle of radical symmetry between human and nonhuman actors, which dissolves modernist demarcations between living, consciously acting, and communicative subjects on the one hand, and dead, deaf-mute, and merely instrumental objects on the other, that is: between culture and nature, man and machine, society and technology.[6] Instead, it focusses on the hybridity of socio-technical collectives, on the heterogeneous networks, the imbroglios of human *and* nonhuman "actants".[7] The question "who acts" is thus expanded into the question "what acts". But can objects act at all? And can they be held accountable for their actions? Clearly, in addition to the question of who or what, we also have to face the serious question of what we in fact mean by "an actor", by "action", and by "responsibility". ANT has placed not only the attribution, but also the very substance and meaning of these qualifications firmly on the agenda.[8] Hence, this "theory" is manifest in most of the contributions to this volume – sometimes in an affirmative sense, sometimes from a critical persepective. [9]

### *Normativity*

The dispute about agency is more than a theoretical game. It has profound political and normative consequences. Who or what is endowed with what kind of capacities to intervene and change the co-production of science, technology and society? Unequal distributions of agency imply unequal capacities for political action. But different kinds of agency also imply different styles and places of politics. Thus, with agency comes politics – both empirically and conceptually.[10]

Take the issue of agency and structure. Should agency be ascribed only to individuals, or to social systems and structures as well? That makes an important difference to how we deal with normativity. In the first case, restricting agency to individuals only, normativity is perceived as primarily a matter of individual accountability: a person's actions are critically judged by a set of ethical, moral, or legal rules which are relatively independent of those very actions. Here, we presuppose an external moral order with strongly critical features. In the second case, granting agency to social relations and institutions as well, normativity tends to be perceived as an internal affair – inasmuch as norms and values are already embodied in social systems and structures. In this view, the moral order and the social order are internally related, instead of the first being the exogenous, critical measure for the latter. But then morality becomes almost synonymous with normality – moral is what is normal and vice versa. How then can we maintain an external, critical stance? On what grounds can we judge normatively and act politically?

These questions become even more urgent if we also grant agency to nonhumans. The problem then is not whether morality/normativity is thought to lie outside or inside the social order, but whether we can imagine a normative position outside the co-production of technology and society, i.e., outside the hybrid socio-technical network of humans and nonhumans. If so, one could reasonably argue that the notion of co-production and the idea of radical symmetry have not yet been taken seriously enough, since, apparently, an exclusive position is reserved for human beings as reasoning judges. If not, and morality is simply taken to be a part of the process of co-production, what space remains for normative evaluation? And what would actually be meant by a normative politics of technology? If normativity is co-produced as well, and thus only to be understood "from within", how can we translate this idea politically? Wouldn't that also require a shift in our very concept of politics?

## Contributions

These are the questions that inform the various contributions to this volume. Not every author seeks a balance among the three main themes. Some focus primarily on the conceptualisation of co-production – especially in terms of agency and structure; some concentrate on the social and/or moral agency of nonhuman actors; others consider the implications for a normatively inspired politics of technology. Moreover, the themes are raised in various ways. Some authors engage in rigorous theoretical and conceptual analyses; others take the empirical route of analysing actual developments and concrete technologies.

The contributions to this volume are grouped into three sections. The first section deals with the distribution of agency between various human and nonhuman actors in the co-production of technology and society. Disco relates the notion of co-production and the implicated agency of nonhumans to traditional sociology; Brey reconstructs different interpretations of agency within the field of science and technology studies; and Oudshoorn et al. discuss the pros and cons of the concept of distributed agency by means of an empirical case study. In the second section, it is not the distribution and attribution, but the very constitution of both human and nonhuman agency that is the key problem. Stemerding and Nelis, in their case study on cancer genetics, analyse how different kinds of human agency are produced in response to new technological developments in this field. What human beings are is thus technically mediated. Verbeek and Kockelkoren both elaborate on this notion of "technical mediation" – Verbeek in the context of industrial design, Kockelkoren in relation to art and perception. The third section, on the politics of agency, treats the normative consequences of the co-production of technology and society. Elzen traces the implications of the hybridity of social and technical relations for a successful policy of innovation in a study of traffic and transport. Swierstra and Jelsma discuss the possibilities and limits of an ethics of engineers, given the social and technical complexities of design practices. And lastly, Popkema and Harbers, analyse the politics of artifacts – specifically, a prenatal screening test – in relation to the traditional politics of technology. In the epilogue, the different threads are pulled together by exploring a new conception of politics and democracy in the hybrid context of technologically mediated societies.

### *The Distribution of Agency*

Within the sociological tradition, technology is mostly treated as an instrument in human hands, thus conceptualising technology as dependent on (inter)human goals, intentions, interests, or power relations. Yet, both the notions of co-production and of nonhuman agency contest this priority of humanity over technology. Does this mean we should leave mainstream sociology behind us as a humanistic misunderstanding? Perhaps the price of such a move is too high – both in an analytical sense (losing all kinds of traditional sociological concepts) as well as politically (losing human-based normative grounds for critique and intervention). Should we therefore revise these notions of co-production and nonhuman agency in order to reconcile them with traditional sociology and theory of action? This is the issue that informs the first two chapters: the relation between the insights of science and technology studies and the more traditional notions about social order and agency.

In his contribution *Back to the Drawing Board: Inventing a Sociology of Technology*, Cornelis Disco starts from two observations. First, established academic social theory has had little or nothing to say about the role of technology in society right from the start. Therefore, secondly, some branches of recent science and technology studies – actor-network theory in particular – are very skeptical about the usefulness of sociological theory for the study of this social role of technology. Disco analyses and criticises this mutual hostility – first by telling four "technology parables", each showing a different aspect of the hybridisation of human and nonhuman agency, and by subsequently discussing three efforts to integrate technology studies and classical sociology. With a bit of pushing and shoving, i.e., a revision of agency from a property of discrete entities (like reflexive human beings) into a quality distributed among heterogeneous entities as elements of hybrid networks, technological artifacts and the dynamics of technological changes can be encompassed within the theoretical framework of general social theory. Disco argues that "... one can have one's nonhuman actors and eat the cake of sociology, too".

In his *Artifacts as Social Agents*, Philip Brey deals with the same issue, the agency of nonhumans. However, he does not relate this directly to social theory (Disco's point of reference) but reconstructs three perspectives within the field of science and technology studies itself on the social role of artifacts: realism, social constructivism and "hybrid" constructivism. While realists talk about the power of technologies for effecting social change, thus attributing agency to artifacts, social constructivists deny that artifacts have inherent properties that make them agents on their own. In Brey's reconstruction of the social constructivist perspective, the agency of artifacts is always dependent on social processes of attribution and the imputation of meaning. In turn, hybrid constructivists (mainly actor-network theorists) reject an assumption shared by the realists and the social constructivists: that there is a neat distinction between a social, human domain and a material, nonhuman domain. The agency of artifacts within this third perspective is framed as the result of their being embedded in a socio-technical network of human and nonhuman entities. Brey weighs the achievements and deficiencies of these three perspectives, and develops a fourth one called "differentiated constructivism", reintroducing (*pace* hybrid constructivism) a distinction between social and material sources of the agency of artifacts, but without tumbling into the pitfalls of realism and social constructivism.

Disco and Brey thus deny agency as an a priori property of independent entities – either human or nonhuman. Instead, agency is seen as a relational category, i.e., the product of interactions within hybrid, socio-technical networks. Changes in these networks alter the attribution and distribution of agency between involved human and nonhuman actors. But, to what extent does this distribution of agency imply a corresponding distribution of responsibilities? Do the distributions of social and moral agency run parallel? No they don't, and for more than one reason as Nelly Oudshoorn, Margo

Brouns, and Ellen van Oost argue in *Diversity and Distributed Agency in the Design and Use of Medical Video-Communication Technologies,* a study of the design, implementation, and use of video equipment that enables parents to visit the intensive care unit of a hospital in a "virtual" sense. An analysis of the "Baby Watch", as this system is called, shows that social and moral agency *do* not run parallel as far as their distribution among humans is concerned; and they *cannot* run parallel as soon as we include nonhuman actors, since these cannot in the last be held responsible. Inspired by feminist technology studies, Oudshoorn et al. demand special attention for "silenced voices" in the development of new technologies, which include users in general and less powerful user groups, like women, in particular. For that purpose, these scholars explore ways in which new technologies contribute to (a)symmetry in agency and control among the different actors involved – both human and nonhuman. To do this, they work with the ideas of "script" and "distributed agency" from actor-network theory. The script approach is attractive because it blurs the boundaries between design and use, between experts and laypersons. But, as the authors argue, in real-life practice the concept still focusses on designers' representations of users, greatly to the detriment of users' representations of technologies. Moreover, it tends to neglect diversity in agency, power, and control between – as well as within – different user groups. Since the concept of distributed agency takes agency not as an a priori given feature of an actor but as the outcome of interactions between the heterogeneous actors in the network, it could possibly avoid these shortcomings of the script approach. However, as the Baby Watch example shows, the notion of distributed agency also loses touch with asymmetries within this interaction process – factual asymmetries among humans in terms of power and principled asymmetries between humans and nonhumans in terms of responsibilities. Symmetry, the authors conclude, echoing Brey's argument, is a useful analytical instrument, but in many cases, human actors still make the difference.

### *The Mediation of Agency*

This latter conclusion, by which decision making capacities are in the end again attributed exclusively to human actors, is questioned in *Choices and Choosing in Cancer Genetics* by Dirk Stemerding and Annemiek Nelis. They shift our attention from the possible agency of artifacts to the collective production of human agency, i.e., to the creation of particular subject positions as an effect of mediations in emergent socio-technical networks. The authors unfold their argument in the course of a reconstruction of new developments in the field of cancer treatment, particularly the use of DNA technology in the diagnosis, therapy, and prevention of familial adenomatic polyposis (FAP), a congenital disorder leading to intestinal cancer at an early age. Whereas actions and decisions in the FAP field are traditionally legitimised in terms of prevention and the well-being of patients, the introduction of DNA technology provokes a vocabulary of self-determination where patients are not only subjects in need of preventive care, but also free and autonomous subjects dealing with new opportunities and choices. That, at least, is the official line. Stemerding and Nelis show how these choices are embedded in professional practices, medical procedures, standards, and institutions. Accordingly, they consider autonomy and freedom of choice not as pre-given normative guidelines for a critical evaluation of daily practices, but as possible results of developments in medical-technological regimes. Moreover, they show that changes in these regimes also bring about changes in the way autonomy and free choice are realised in practice. The autonomous, free-choosing subject has different faces, Stemerding and Nelis conclude, thus challenging not only mainstream medical ethics in particular, but also overly rationalistic conceptions of human agency in general. The principle of radical symmetry is a double-edged sword because it attributes agency to nonhumans, but it also subverts the agency of humans.

While Disco, Brey, and Oudshoorn et al. acknowledge the benefits of this principle, in the end, they regard it as overly monistic. Peter-Paul Verbeek, meanwhile, takes precisely the opposite tack and accuses Latour and other actor-network theorists of a failure of nerve. As he argues in his *Artifacts and Attachment: A Post-Script Philosophy of Mediation,* they don't take their own ideas about "things" as agents in the co-production of technology and society seriously enough. Take, for example, Akrich's approach to technological artifacts in terms of their scripts, or Latour's views on technical mediation – two applications of what Brey calls hybrid constructivism. Even here, Verbeek argues, "things" are ultimately reduced to the social processes of the formation and attribution of meaning, just as in social constructivism. Humans continue to be the measure of all things – despite Latour's emphasis on radical symmetry, hybridisation, and interobjectivity. Verbeek tries to counter this willy-nilly social preoccupation with a material approach to things. He urges us to look at what things themselves are doing, instead of looking at them as vehicles of human meanings and aims. For this purpose, Verbeek invokes the work of contemporary phenomenologically inspired philosophers of technology. Don Ihde's notion of technological intentionality, for example, can be used for a re-interpretation of technical mediation and delegation. Verbeek exemplifies his argument by the activities of *Eternally Yours* – a Dutch association for sustainable design.

Verbeek thus explicitly rejects technical mediation as a single, one-way track, i.e., humans delegating agency to nonhumans, which still presupposes the mastery of human subjects over material objects. Instead, the mediation process is interpreted as a double, two-way track where human beings are also mediated and transformed by technological developments. The same holds true for Petran Kockelkoren using the notion of technical mediation in order to specify human being-in-the-world, i.e., the technologically mediated relationship between human subjects and their environment. In his *Art and Technology Playing Leapfrog: A History and Philosophy of Technoèsis*, Kockelkoren focusses on the problems of sensory perception of the world, traditionally both an epistemological and an aesthetic issue. People are "ex-centric", the philosophical anthropologist Helmuth Plessner argued, and therefore they do not have direct access to the world around them. On the contrary, their senses are always mediated – by language, by art, and by technology. This mediating capacity of technology to open up reality and, in co-evolution with images and ideas, to give shape to culture is called "technoèsis". Using examples from the common history of art and technology, Kockelkoren analyses technoèsis as an ongoing process of disordering and reordering, decentring and recentring our subjective senses, time and again leading to the domestication of new experiences – indeed, a Foucauldian disciplinary process. But what then remains of the autonomy of the artistic and/or epistemological subject? Is it lost in a bodily and materially mediated process of normalisation? Kockelkoren shows this pessimistic diagnosis to be as erroneous as its optimistic counterpart: the freely criticising subject-artist. Autonomy itself, he argues in line with Stemerding and Nelis, is part and parcel of mediation processes. It is not the condition for, but the result of, a historically specific technoèsis.

### *The Politics of Agency*

The first two sections of this book focus on the issues of co-production and agency. Except for Oudshoorn et al., the ethical and political consequences of these issues have not yet been touched upon. The last three chapters delve forthrightly into this issue of normativity.

Boelie Elzen, in his contribution *Taking the Socio-Technical Seriously: Exploring the Margins for Change in the Traffic and Transport Domain*, traces the (im)possibilities for intervening in the developmental course of technological regimes. To realise certain societal aims, like a sustainable traffic and transport system for example, two policy approaches are generally deployed – a behavioural and a technological one. First, efforts are made to influence the behaviour of users and consumers – to reduce the number of car kilometers, for example. If this approach proves to be unsuccessful, as so frequently happens, a second, a technological approach is often activated, such as producing cleaner cars. However, this distinction between behaviour and technology neglects their mutual dependence, i.e., the co-production of social relations and technological artifacts and systems. As soon as we take this mutual dependence as a starting point for analysis, that is, by considering the traffic and transport system as a socio-technical regime with particular patterns of development, new possibilities for realising those societal aims arise. One of these possibilities is the creation and preservation of so-called "technological niches" – a space for experiments parallel or counter to the dominant technological track. On the basis of several examples, Elzen argues that the success of these experimental niches depends on the achieved degree of integration of the behavioural and technological approaches to change.

Taking for granted the co-production of technology and society and thus the incorporation of norms and choices in technological artifacts and practices, Tsjalling Swierstra and Jaap Jelsma, in their *Trapped in the Duality of Structure: An STS Approach to Engineering Ethics*, ask whether this material embodiment of normativity leaves any room for a positive ethics of engineering and engineers. After all, if we take the distribution of agency throughout the hybrid *collectif* of humans and nonhumans seriously, what then remains of the moral responsibility of individual engineers? Not very much, as Swierstra and Jelsma demonstrate by the results of their inquiries into the practice and self-evaluation of engineers involved in an experimental impact-assessment project at the University of Twente. Mainstream engineering ethics, they argue, though itself a product of the sociological turn in science and technology studies, still focusses on individual responsibility as exemplified by the heroism of whistle-blowers, and thus is in constant danger of moralism, i.e., charging engineers with moral standards to which they cannot live up to. Engineering ethics, according to Swierstra and Jelsma, should pay more attention to the enabling and constraining effects of socio-technical networks, those hybrid *collectifs* of humans and nonhumans, since these networks set the institutional conditions for moral responsibility and accountability on the level of individual engineers. Thus, Swierstra and Jelsma contest moralism while acknowledging the *social* and *political* agency of networks. But that is not to say that these networks have *moral* agency, which relieves engineers of their individual responsibilities. On the contrary, only human actors can act morally, according to Swierstra and Jelsma. Therefore, they end up with a "second-order" responsibility for engineers, urging them to strive for institutional conditions in favour of a realistic enactment of – always individual – moral responsibility.

Though Marcus Popkema and Hans Harbers, in their *The Cultural Politics of Prenatal Screening*, do not follow Swierstra and Jelsma in their categorical distinction between social and moral agency, their case study about prenatal screening does reveal actual mismatches between the distribution of agency and the distribution of responsibility. Popkema and Harbers argue that the "triple test" – a relatively new pregnancy test – is not merely an innocent technical instrument that just optimises and rationalises prenatal selection procedures. On the contrary, the test behaves like a "techno-normative artifact", i.e., a technique with a repertoire of normative actions. On an individual level, it changes the way pregnancy is perceived and experienced. On a societal level, it routinises the prevention of the birth of children with Neural Tube Defect or Down Syndrom. Subsequently, the authors compare this politics *in* technology with Dutch governmental policies *on* the same technology. The contrast is remarkable: while the new regime of pregnancy continuously expands, becomes normalised and thus heavily structures individual choices due to the introduction of the triple test, the government, backed up by public debates, tries to restrain and regulate this growing network by mobilising the principle of "informed consent" in order to guarantee freedom of choice to pregnant women – as it turns out, without much success. The politicians' and ethicists' vocabulary of autonomy and free choice seems too distant from the practice of "technological motherhood". From this observation, Popkema and Harbers, inspired by Beck's notion of sub-politics, conclude that another politics of technology is required. Since technology is politics pursued by other means, the politics of technology should also be performed by other means.

In the epilogue, the three issues of this volume are again addressed – not by summarising the different contributions, but by exploring the consequences of both the notions of co-production of science, technology and society and of nonhuman agency for the theory and practice of a politics of technology. The chapters of this volume can be read as an emerging argument for the idea that technology has its own kind of (sub)politics, i.e., the incorporation of normativity in materialities like technological artifacts and systems.[11] But what does this idea of *politics in* technology mean for *policies of* technology – for steering and regulation, for constructive technology assessment, strategic niche management, scenario studies, democratising technology, and social learning mechanisms, to mention only a few broadly discussed policy instruments? How to rethink politics and normativity in the light of nonhuman agency?

This very question is dealt with in the epilogue in the context of an ongoing debate about the supposed lack of normative ambitions and the political irrelevance of science and technology studies (STS) – an accusation which has been made twice, on different levels, by different groups of critics. First, on the *epistemological* level, by normative/rationalist philosophers of science. With the empirical turn, they argued, every prescriptive, normative ambition of earlier science theory was abandoned. This accusation was countered within the STS field by a revision of the concept of "science" – from a body of knowledge to materially embodied practices, from a propositional view on science to a performative view. Second, the accusation of normativity impotence has been made on a more *political* level by normative political philosophers and advocates of the former Science & Society movement. The charge is that having restricted itself to mere description, STS has thereby reneged on its critical, normative mission. While the first accusation concerns normativity in matters of truth, the second concerns normativity in matters of justice. The first is about good knowledge, the second about the good life. The substance differs, but both accusations touch upon a common issue: What do we mean by "normativity"? In his epilogue *Political Materials – Material Politics*, Harbers suggests countering the second accusation in the same way as the first one – now by changing the very conception of "politics" from politics as deliberation about, and justification of the good life to politics as the making and unmaking of different worlds – from legitimation to experimentation.

### Notes

1 In this book, we shall generally use "co-production" instead of the often-used notion of "co-evolution" in order to avoid all kinds of evolutionary connotations and to emphasise constructivist associations. The production of novelty, for example, is not always a blind process.

2 For example: seamless web (Hughes 1986), heterogeneous networks (Law 1987), socio-technical ensembles (Bijker 1995[a]), the hybrid *collectif* (Callon and Law 1995), and socio-technical regimes (Rip and Kemp 1998).

3 Here again, different concepts are proposed, such as script (Akrich 1992), program and anti-program (Latour 1992), inclusion of relevant actors (Bijker 1995[a]), and the intentionality of technology (Ihde 1990).

4. See, among many others, Giddens (1984) for the classical formulation of this general issue in social theory. See Fischer and Ravizza (1993) and Fischer (1999) for a review of discussions about responsibility within liberal political theory. See also Barnes (2000), who criticises individualism and voluntarism within this liberalist tradition. Elaborated and sympathetic as his argument may be, Barnes remains

within the confines of a human-centred sociology, almost fully passing over the (next) issue of nonhuman agency – an issue that is not so much about the individual and the social (Barnes's problem), but about the very definition of both individuality and sociality.

5 A theory, which actually does not want to be a theory but a heuristic, a way of looking, thinking, and doing research, according to Latour (1999[b]). Moreover, ANT does not stand alone. It is one of the STS elaborations of a much broader *materialist turn* in social and cultural theory, i.e., the acknowledgement of the crucial role of material objects (things, artifacts, technological systems, etc.) in the production of social order and change. See Pels, Hetherington, and Vandenberghe (2002) for a recent collection of contributions to this materialist turn. For earlier contributions see, e.g., Appadurai (1986), Latour (1988[d], 1996[a], 2000), Tilley (1990), Haraway (1991), Ashmore (1993), Harbers and Mol (1994), Law and Mol (1995), Knorr Cetina (1997, 2001), Harbers and Koenis (1999).

6 This methodological and ontological principle is called "radical" since it radicalises the foregoing principle of symmetry, originally formulated for the social study of scientific knowledge ("explain true and false beliefs by the same type of causes"), and subsequently for the social study of technology ("explain success and failure of technological artifacts by the same type of causes"), into a general principle for the study of socio-technical worlds ("treat culture and nature, humans, and nonhumans, social and technical matters in the same way").

7 See Callon (1986, 1987), Latour (1991, 1993[b], 1999[a]), Law and Hassard (1999).

8 That is why Latour and others have replaced the concept of "actor", for example, by that of "actant", i.e., any actor leaving traces – irrespective of its being a human, an animal, a text, an artifact, or an object. See Latour (1987).

9 For discussions about human, and especially nonhuman agency, see also Ashmore et al. (1994), Callon and Law (1995), Pickering (1995), Cuzzins (1996), Latour (1993[a], 1999[a]), Gomart and Hennion (1999).

10 Following from agency, normativity is therefore a key issue of science and technology studies – notwithstanding criticisms blaming this field of study for a supposed decline of normative and political awareness and pretensions. See, for example, Scott et al. (1990), Star (1991), Harding (1992), Radder (1992), Martin (1993), Winner (1993), Ashmore and Richards (1996), and Woodhouse et al. (2002). For an argued response to these criticisms, see the epilogue to this volume.

11 A classical source for the notion of politics of technological artifacts is Winner (1980). For the notion of sub-politics, see Beck (1997).

# The Distribution of Agency

# Back to the Drawing Board
# Inventing a Sociology of Technology

*Cornelis Disco*

## Introduction

One of the great lapses of the sociological imagination has surely been an appreciation of the role of technology in society. The "founding fathers" – if we may except Marx – paid it scant attention, and their intellectual descendents have done little better. Mark Shields says:

> The vital sociological traditions of theorising about phenomena such as the state, power, social class, ideology, division of labour, religion, revolution ... have barely touched technology. This is a stunning omission. Shields 1997, 188)

What is stunning is of course the lack of interest in a phenomenon which by all accounts has been one of the prime levers of change in modern societies. The classical mission of sociology, to offer a new reflexive self-understanding for post-feudal, industrial societies, would seem to encourage sociologists to position the study of technology at the very centre of their intellectual programme. Instead, they have marginalised and disdained technology, treating it as a trivial corollary of economic or scientific rationality, and of sociological relevance only insofar as it had effects on other societal patterns (Ogburn 1922; Gouldner and Peterson 1962). Technology has been taken seriously as a sociological phenomenon itself by only a very few sociologists (Gilfillan 1935; Noble 1984). For the most part, it has been left to renegade traditions like Marxism and labour-process theory (MacKenzie 1984), recently reinforced by the new social studies of technology (SST) to unpack the "black box" of technology and reposition it as an authentic societal phenomenon. However, these traditions have adopted more or less sectarian standpoints with respect to mainstream sociology and have reinforced, rather than weakened, sociological prejudices regarding the ontological and epistemological "otherness" of technology.[1]

This is not the place to dwell on the many reasons for the suppression of technology in the sociological project. What we can do here is examine how, given the nature of technology and the deep structure of academic sociology, technology might be incorporated into the sociological program in a way commensurate with its societal importance.

As to the nature of technology, it is now clear that it is far from the straightforward means (or set of tools) that sociologists have generally taken it to be. We shall have occasion to dwell on this point in connection with four "technological parables" in the following section. As to the "deep structure" of sociology, I take that to refer to the essential opposition between (or dialectic of) agency and structure which has been the primal matrix of social theory from the times of Adam Smith, Karl Marx, Emile Durkheim, and Max Weber onwards. In its classical form, this dialectic posits a mutually constitutive relationship between individual human beings (or social groups) and a larger social collectivity. It is a compact way of accounting for, on the one hand, social order and stability (i.e., the Hobbesian problem of how numerous individuals, often at cross-purposes, can maintain stable patterns of interaction) and, on the other, social change (how those stable patterns can evolve or even be dramatically transformed). The scheme expresses a relation between situated social action (agency) and an order of sedimented norms, role expectations, laws and ... technologies (structure). The relation is such that social action is shaped and given meaning by these sedimented structures, but also that social action in turn impinges on social structure, either reinforcing it or causing it to change: i.e., to evoke new patterns of interaction and new sedimentented structures.

Traditionally, this scheme has tended to apportion different types of entities to the poles of agency and structure, respectively. Humans, defined as uniquely endowed with consciousness and intentionality, have been seen as the primary, if not the only, sources of social agency. Non-human entities, e.g., texts, beliefs, and material objects and systems, have been apportioned to the sphere of structure. Technology thus becomes a feature of the sociological landscape rather than an actor on the historical stage. The scheme has also defined human beings as the sole makers of society. Bruno Latour has attacked this "modernist purification" with vigour and imagination (Latour 1990, 2002). For him and others, it has been sufficient reason to reject the sociological tradition *tout court* and to turn to one other metaphysics of the social. One may ask to what extent this is necessary or helpful. This depends on the answers to three additional questions: Is there good reason to challenge the traditional attribution of entities to the categories of "agent" and "structure"? Would such a re-attribution violate the logic of the dialectic or impair its sociological work? Is the dialectic of agency and structure the right centerpiece for a science of society; i.e., would the conceptual work of re-attribution be worth it? Is sociology worth saving for technology? Given what the field of Science and Technology Studies has revealed about technology over the past thirty years, it is clear that the answer to the first question must be "yes". The "technology parables" to be presented below merely confirm this. I will argue that the dialectic of agency and structure is not *essentially* implicated in any a priori ontological distinction between humans and nonhumans. It can work as a formal and methodological scheme quite apart from the contingent attributions of types of entities to one or another of the poles. Finally, in regard to the question of whether sociology is worth the effort of manipulating its DNA, I suggest it *can* be done; I also think it *should* be done, if only because sociology's foundational agency-structure dialectic is still the only approach which incorporates elements of psychology, economics, and history into a unified metaphysics of social action. Sociology provides the only potentially unified approach to modernity as an achievement (or catastrophe) leaving traces in time. It is worth having a world in which one can have one's nonhuman actors and eat the cake of sociology, too.

## Technologies

To address this issue, it will help to have a concrete image of what we are talking about. Following are four stories about material artifacts, i.e., constructs intelligently designed to perform some specific function or task (whether or not they are held to do so in practice).

### *Palm organizer*

> Imagine having your daily schedule, important phone numbers, lists, meeting times and more in one organized place. It's easy and more affordable than ever with the Palm™ IIIe handheld.
> – advertisement for Palm. (www.palm.com)

Up front, advertisements for electronic organisers like the Palm series produced by 3com Inc. portray the new gadgets as productivity enhancers, as tools for organising fragmented lives. The Palm lets us apportion our time in advance. Its literal electronic memory "backs up" our own spotty faculties and infallibly reminds us of what we are to do and when we are to do it. At the same time, the volatility of electronic memory, the ease with which information can be erased, edited, and replaced makes it a highly flexible tool for time, task, and contact management.

Palm Inc. maintains a website including, among other things, a collection of customer testimonials.[2] These reveal that Palm organizers enhance the capabilities of users, but also change their relationships to themselves and others. The testimonial writers invariably experience this as a positive change and consequently tend to fawn over their new "digital pals".

> USER 1
> I am a female sales professional working 50-60 hours while at the same time trying to manage a home, 2 small children, a marriage, etc. I live to be organised but sometimes have trouble keeping it all together.
> I ...charged it and began to enter data. Within hours, I had entered my year 2000 appointments, approximately 75 important dates (birthdays, etc), my children's school calendars, before- and after-school activities, not to mention several customised "to do" lists (daily, weekly, monthly, annually, biannually, etc). Needless to say, I have fallen in love with it...
> Thank you, Palm Computing, for making organisation so much fun!!!
>
> USER 2
> I work in the internet financial services industry and as such have to manage multiple and diverse projects, initiatives and issues. I am always on the move, in meetings or visiting outside the bank. Information is critical to ensure that details are not missed and that I can speak intelligently about the issues. There is invariably insufficient time to prepare, so having the information at my finger tips just as I last saw it on my laptop is absolutely critical for me.
> Here is why my Palm V organiser is now a critical part of my life.
> 1 It fits in my pocket... I always have it with me.
> 2 Easy-Sync: I HotSync with Lotus Notes R5 and individuals across the Bank can view my schedule. I have a custom folder in Notes where my daily news from Slate and CNN are placed by a Lotus Notes "rule". I then HotSync that folder with the Palm V organiser and can read those news emails on the Palm V organiser on the subway.
> 3 Inforover: I read news from Associated Press daily as well as the BBC website so always up to date on news. About 800 – 1000K daily download.
> 4 Project@Hand: All our projects recorded in Project 98 are HotSync'd on my Palm V organiser so in meetings I am always prepared with the full details.
> 5 Thoughtmill: I use this for capturing thoughts and ideas for future reference. Very cool outliner.

6 UltraMoney: Lastly I am so busy I never remember to balance my bank account, so now I view my bank statement in the Palm V organiser which comes from the internet via MS Money 99.

These are paeons of praise in a utilitarian mode. However, they contain subtexts which delineate some of the ironies attached to inviting a machine in to help organise (run?) your life. One of these ironies is the question of who (or what?) is organising what (or whom?). For example, what kind of self-discipline is involved in using a Palm as a tool and what is it like living with the tyranny of infallible and literal memory? Who may co-opt this memory in order to discipline the user across spans of space and time?

User 2, for example, begins with standard praise for the Palm as a "productivity tool". However, the subsequent description of the Palm-in-use as a "critical part of my life" makes us wonder what kind of tool this is. It seems that in order to use it in the volatile context of the financial services industry, user 2 must subject himself to a strict daily regimen of data gathering and digesting. Given how much of his workaday efficacy is delegated to the Palm, anything less amounts to functional failure of user 2 in his business context. User 2's subtext contrasts with the paeon to efficiency in the main text; it is actually a confession of subjection to the device. Perhaps this is not adequately put. The point is that the Palm organizer enables user 2 to arm and discipline himself in accord with his employer's needs. The impression is not that user 2 thus "wins time" for himself but rather that, thanks to the pervasive role of the Palm in his life, user 2 is able to mould himself into a more perfect employee of the bank (and hence, presumably, advance his career). The Palm thus effectively becomes a personalised tool for translating the demands of employment into a self-imposed regime. But then whose tool is it, and what exactly is the status of a human actor "armed" with a Palm or, perhaps, "chained" to a Palm and subject to its tyranny of perfect memory?

This simultaneous exercise of self-discipline and other-discipline by means of the Palm also extends to private and romantic matters, as the following citation suggests.

USER 3

I've just received a Palm III™ connected organiser as a Christmas gift from my husband and I must say I am in love... Not only have I dumped every contact name I have into to this sexy device, but the design of this device fits my hand like a new friend.

Although my husband does not mind my new found love affair, he has insisted that I pre-schedule time with him and is quite pleased with him-

> self over the control it provides him to gain access to my schedule. He has even pre-programmed a year's worth of scheduled "dates" and set up the beeping mode, so I won't forget. What a sweetie, xxoo.
> PS: He doesn't know a thing about computers, so he must have worked late into the night to figure out how to enter in all the information and get it to work.
> Great work in the design and layout. All I can say is ooh-la-la.

In this three-player figuration (user 3, her husband, and the Palm) the Palm mediates the availability of user 3's time. In particular, the husband has co-opted the Palm to stake romantic claims to his wife's "schedule", claims which user 3 coyly allows the Palm to register and which she suggests she will honor. But explicit sex seems reserved for the Palm itself. User 3 claims to be "in love". But is she in love with her husband for giving her the Palm or in love with the Palm? The husband is "a sweetie", but the Palm is "sexy", it is "a new friend", and all user 3 can say is "ooh-la-la". Is user 3 simply the Emma Bovary of the informatics era, or does she constitute a new exotic-erotic kind of cyborg together with her Palm? Is the nature of the Palm, its "features" and "design", responsible for this romantic drama?

What do we learn from this? In the first place, that we need to take a second look at the facile ontological division between humans and "things". This does not mean throwing it overboard without further ado. The Palm testimonials suggest that it is often difficult to decide who (or what) is programming whom (or what). The human agent disciplines the Palm to provide certain information on call, but the Palm subsequently turns around and disciplines the human.

What can we mean when we say the Palm "disciplines" the human? It is a simple enough matter to assert that the Palm is an "agent" and thus "acts", but what does this mean sociologically speaking? Few would be prepared to endow the Palm with the same quality of sentience and reflexivity as ourselves, so that its "acting" must be of a different order. It is clear that a Palm devoid of a human is meaningless; it is simply an orderly configuration of elements with particular performative potentials. This does not hold for the inverse, i.e., a human without a Palm – however much Palm Inc. may try to convince us otherwise. So – *as long as the device is working to rule* – agency can be attributed to the Palm only in a derivative and ironic sense. The Palm acts on its human operator, but only by a kind of blanket permission, on the basis of a prior compact by which the human sets the Palm up to exert discipline over him- or herself at some future time. The agency of the Palm thus derives from the voluntary submission of the human to demands made by a past self on a future self. The Palm's infallible memory becomes an instrument for storing demands on and information relevant for the future self. Like Marx's worker, the human actor is confronted by a temporarily alienated form of his own intentionality locked up in the microcircuits of the Palm. Could this be the (narcissistic) secret of the Palm's erotics? Inasmuch as the future is unpredictable, the moment at which the Palm presents its alienated demands may be totally inappropriate and may conflate past and present in odd ways. This amplifies the illusion of the Palm's own agency. The Palm cannot of course do more, nor less, than it is instructed to do, but the precise circumstances in which it does what it must can change the original meaning of the information entered in the past. In this sense the "detour" of the Palm has introduced an element of creative novelty into the ongoing self-organisation of the human. The Palm as partner in the reflexive self-discipline of ongoing life transforms the human actor into an informationally competent and punctual actor – but also an actor set up to be invaded at times by his own past intentions. This actor is a hybrid actor, a human-with-Palm, a "palmed Human".

We must conclude that the issue is not so much whether humans or "things" have agency, but that the agency of humans and things, such as it is, is modified by the "hybridisation" of agents in the form of humans-with-tools. In more general terms, human agency is so transformed by the technologies involved in the constitution of that agency, that in a technological age it does not make sense anymore to speak of human actors apart from their technological accoutrements. Unlike a rose, a Palm user is not a car driver is not, as we shall see, a designer of superconducting solenoid magnets.

### *Designing magnets for the G-2 experiment*

Experiments in high-energy physics are organised as collaborative efforts among a number of locally based physics groups. Typically, the collaboration is sited at one of the large particle accelerators, and participating physicists fly in to attend meetings and participate in the ongoing work. To perform their experiments, the collaborators must first design and construct a "detector". These detectors transform the streams of high-energy particles produced by the accelerators into "events" that physicists can study. Detectors are typically large and complex devices, taking many years to design and construct. This process, even though the setting is exotic, is typical of design processes in general and reveals a basic feature of technology, namely that it is purposively constructed in order to perform a particular function. This does not rule out that designers may disagree on the function to be performed and especially on the way to implement the desired function in a design.

The following account of the design of a component of a high-energy physics detector shows both the purposiveness and the contentiousness of the design process. The component in question is a 14m diameter superconducting magnet ring for the Muon g-2 experiment which has been on-line at Brookhaven National Laboratories at Upton, New York, since 1998 (Disco 1998). The purpose of the experiment is to measure the so-called "anomalous magnetic moment" of a particle called the muon to a hitherto unprecedented degree of precision. This requires an extremely strong and very precise and uniform magnetic field along the entire length of the 14 m-diameter coil. This was *terra incognita* for magnet designers and in fact proved to be a formidable engineering challenge.

It took only a few meetings of the magnet coil group to discover that there were serious disagreements on at least four aspects of the coil design. The minutes of Feb. 12, 1987, indicate that for each aspect, two main options were under discussion.

- A Winding configuration: "pancake" vs. "continuous" or "zig-zag".
- B Material for the coil mandrels (supports): aluminum vs. stainless steel.
- C Winding technique: "ferris" vs. horizontal.
- D Method of coil-cooling: Epoxied package in contact with liquid He cooling tubes vs. Immersion of coil package in liquid He cryostat.

Not all combinations were being pursued, so that in practice only two or three coherent "designs" were actually circulating – each championed by one of the participating groups. In the coil-group minutes, several of the alternatives were evaluated as follows:

> A2 needs more delicate filling of voids; B1D2 needs welding of the aluminum coverplate, very risky; C2 needs tall building; B1 allows extrusion of the aluminum profile, cooling tube for liquid helium included.[3]

In the Feb. 26, 1987 meeting, for example, the issue of mandrel material was discussed. RS (a Brookhaven physicist) argued for stainless steel because "the pitfalls are best known". This provoked FK, the CERN physicist chairing the group – and also writing up the minutes – to the following encomium on aluminum:

> This does not rule out aluminum cryostats! Any proposition, reasonably worked out, will be thoroughly discussed, since we are all aware that aluminum allows extrusion, incorporation of helium cooling duct, vastly superior heat conduction and absence of magnetic disturbance.

On March 26, there was a joint meeting of the three groups then working on different aspects of the detector design. The chief engineer of the coils group reported as follows:

> The group struggles with the material for the helium vessel: stainless steel or aluminum... stainless steel is more conservative, but the extreme slenderness of the coil section with respect to the coil radius made us look for other material combinations in which an aluminum tank or aluminum strips wound together with the conductor are possible alternatives. The conductor fabrication is under control. The leads are, as always, difficult to realise, in particular for the outer coils, where they have to pass through the back leg of the magnet. The coil winding is still under discussion. The coil support is tricky because of tight space, large forces, and low heat loss.[4]

The battle over winding methods was particularly fierce. On April 28, 1987, the chief mechanical engineer of the Yale group published a memo on "Evaluation of Superconducting Coil Concepts" again advocating "continuous winding" as opposed to so-called "pancake winding":

> We find that during several meetings of this subgroup the general tendency was mostly in the direction of pancake coil construction. As a matter of fact, continuous winding coils were not seriously considered, and the strongest argument was that pancake was "the way it was always done". (Disco 1987)

In the event, the entire controversy was settled several months later by the intervention of a group from the Japanese national accelerator facility KEK. This group had a novel idea – already implemented in smaller magnets – for winding the coils "inside-out", i.e., from the mandrel inwards. Moreover, the group had a generous budget and offered to supply a quantity of "spare" superconductor material. Within a month, the virtues of the KEK design had dissolved resistance in the coil group, and it had become the preferred design for the coil configuration and winding method. Although its implementation was still far from routine, the design was sufficiently coherent to resolve the other bones of contention which had paralysed the group until then.

This "design parable" differs from the first one about the Palm organiser. It shows another, but equally fundamental, "phase state" of technologies. While the parable of the Palm showed technology as a device-in-use, modulating agency and social order in a wide range of social settings, the parable of the muon g-2 coils shows technology in the laboratory, as a device-in-the-making: an as-yet-uncertain crystallisation of social purposes in a material configuration. Several points should be emphasised:

1 The design process is an effort to define and master the future behaviour of an artifact. We should add: not only its manifest and desired properties, as in the g-2 example, but also its intended and unintended side-effects, dangers, and risks. Hence, understanding what goes on in the design process is a prerequisite for understanding the potentials of the artifacts that come out of it, or are likely to come out of it – although it is unlikely to be enough to predict the exact ways an artifact will turn out, i.e., its (quite possibly ambiguous) "societal career".

2 Artifacts are designed to function in stable and predictable ways. This encourages the use of non-living elements insofar as these are generally more stable and predictable – though often less flexible – than living elements like animals or humans. Superior stability and predictability are reasons why in advanced societies so much of human agency is "delegated" to machines (Latour 1987). Artifacts become important material anchors for social action, replacing older forms of co-ordination and socialisation. In high-energy physics with its demands for superhuman performances, such delegation is absolutely necessary – humans simply can't do the job – but the stability requirements are at least as critical. As the chief engineer of the coil group noted in a review:

> The stability is a big problem: mounting concentric at room temperature, expecting it to be concentric at cryo-temp and last but not least cope with the expansion when the current is ramped up, while the outer coil is intrinsically unstable – all this demands superior engineering.[5]

3 Designers conceive of the artifact to be made as an actor. As they work, they are constantly trying to predict how the structure they are trying build will behave given particular arrangements and ambient conditions (Bucciarelli 1994). They do this on the basis of what they know about similar structures in similar situations as for example in the following commentary: "FK points out that the helical winding method leaves voids which are alternately on top or on bottom of the coil, but the magnetic forces tend to push them all to one side, hence half the layers may slip when the coils are energised" (minutes March 26). Some options seem beyond the cognitive pale. Then recourse is had to measurements, models, prototypes and calculations to acquire insight

into expected behaviours. For example, the minutes of the coil group contain the following exchange. A physicist SK is cited as predicting that "permeability variations in the stainless steel weld could be swamped by a strip of high permeability material". This prediction is qualified by the writer of the minutes as "a statement clearly in need of quantification and research on adverse effects".

The discourse of behaviours of these material structures is not of course a discourse of motives, intentions, and strategies such as would be the case were a political coalition the object of design. Here, and characteristic of technological design in general, the discourse of behaviours is of behaviours as governed by what, for lack of a better term, we call "natural law". Let us define this as the set of well-tested propositions and theories about how material objects behave under specified conditions. Canonical formulations of "natural law" (what we know about nature) are the substance of the textbooks of the natural and engineering sciences. The interesting property of natural law from the perspective of design is that it in theory allows for determinate predictions about the behaviour of material structures. Of course, this is only in theory. In practice, as the deliberations of the coil group make clear, there is always insufficient knowledge and insight, both into the properties of the structures one is building with and into the prevailing conditions they will encounter.

These conditions are in part also subject to "natural law", but in the final analysis they also include an encounter with society, with human organisations and purposes. In the case of the g-2 experiment, this is the encounter of the detector with the standards of evidence prevailing in the high-energy physics community (Knorr-Cetina 1999). Are the magnets sufficiently stable and uniform to warrant confidence in the data and the conclusions they have helped to produce and which they tacitly underwrite? For other design projects like microwave ovens (Cockburn and Ormrod 1993), diesel engines (Hård and Knie 1999), or storm-surge barriers (Disco 2002), this encounter occurs elsewhere and in different contexts, but inevitably it does occur.

In this view, design is nothing more nor less than a process of incorporating nature into society. The result is neither the one (classical Nature) nor the other (classical Durkheimian society as "moral order") but a thoroughly hybrid sociotechnical order in which machines, tools and devices co-act with humans. What these artifacts do, and can do, and what humans do, and can do, are profoundly altered by the new hybrid juxtapositions – by technology-in-society. This is why design engineering is not enough, but also why classical sociology is not enough.

4 Although not highly visible in the g-2 account itself, this hybridisation of actors and agency occurs not only in contexts of use, as in the Palm parable,

but also in contexts of design. Indeed, how could it be otherwise, since design contexts are also contexts of use, albeit not of end-products, but of testing devices, prototypes, materials? The point is that design (and certainly design in an esoteric field like high-energy physics) is itself accomplished by hybrid actors. Physicists and engineers would be powerless without an elaborate array of measurement and test devices which enable them to assess the consequences of different design decisions prior to committing significant resources of time and money.

*Human calculators*

> ... I shall give a brief excerpt from the memoirs of an early member of the WPA Mathematical Tables Project in New York City. This project was established in 1938 with a very small number of mathematicians and a fairly large number of people from the relief rolls of the Depression. The people who came from the relief rolls were a varied sort, and more than rusty in their arithmetic. Therefore, they were divided into four different groups. One group was to do addition, a second group to do subtraction, a third to do multiplication, and the fourth group to do division and check the results. The people were installed in an abandoned stable in New York City, and the four groups were seated facing the four walls of the room. Each group faced a wall on which there was a large poster giving them their most important instructions, and to keep negative numbers straight, each person was given both black and red pencils to work with. The poster giving instructions for the addition group said:
>
> Black plus black makes black.
> Red plus red makes red.
> Black plus red or red plus black, hand the sheets to group 2. (Slutz 1980, 471)

What is disturbing about the situation described in this citation? It is of course the panoptical nightmare, the Orwellian dystopia of reducing human beings to cogs in a machine. Humans here were operatives possessing fragments of instrumental competence. The whole, the calculating machine which they produced by their fragmented labours, had no meaning for them; it added up only from the perspective of the expert masters.

The Mathematical Tables Project exhibited a shocking disregard for modernist distinctions between humans and machines. The project mobilised all the usual Taylorist ploys in order to transform intransigent human workers into obedient *functionaries*. Skills were fragmented, categorised and apportioned to different workers according to ability. Rules of procedure were thoroughly explicated and reinforced by texts and material cues and instruments. Routing of work followed explicit instructions allowing the minimum possible of individual discretion: "Black plus red or red plus black: hand the sheets to group 2".

Therefore, the question this example raises is the following: How is the Taylorised human-based calculating collective designed and operated by the mathematicians of the WPA Mathematical Tables Project any different from, say, the gear and relay-based desk calculator or the silicon-based modern digital computer? If there is no practical difference, what are the consequences for the classical attribution of agency (morality) to humans and of mere mechanical functionality (instrumental means) to artifacts composed of nonhuman components? To turn Primo Levi around: "What is an artifact?" Or better perhaps: "What is an artifact made of?"

The physicists and engineers in the g-2 story seem to be busy designing an artifact composed entirely of nonhuman components. In this design process, humans (except, of course, the designers themselves) seem a long way off. But ultimately they are there in the form of the physicists who are going to have to get the detector to produce compelling data. The physical detector must be designed to take its part in a "hybrid ensemble" (Callon and Law 1995) consisting of the machine and the physicists and engineers who will ultimately use it to produce data about the muon. In the context of high-energy physics, where the always minute data traces are easily wiped out by systematic or transient "noise" in the detector, operability means total transparency. Physicists must know at all times what the precise condition of the detector is so that they can distinguish data from noise (Knorr-Cetina 1999). This knowledge is based both on a priori confidence in the stability and performance of the machine and on real-time monitoring of its performance. Both modes of confidence depend on crafty design. Hence, although the proximate design labour described above concerns the construction of a nonhuman apparatus, i.e., a machine in the classical sense, the mediate aim is a "hybrid collectif" (Callon and Law 1995) involving both human and nonhuman components.

The notion of "hybrid collectif" suggests a spectrum ranging from artifacts with predominantly nonhuman components to artifacts with predominantly human components. The g-2 magnet coils are clearly very near the purely nonhuman pole, and the WPA Mathematical Tables Project is very near to the purely human component pole. However, just as the g-2 magnet assembly-in-use will not be purely nonhuman, the human calculator is not purely human. The human calculator is again a "hybrid collectif" consisting of human operatives and overseers, but also of a set of tools and props: coloured pencils, paper, texts, chairs, tables, etc.

The sociological reflex encourages us to call the human calculator an *organisation* with strict rules, hierarchies and bureaucratic discipline. This is because it appears to be an orderly and centrally disciplined arrangement of human actors. What advantage is there in thinking of it as an *artifact* in a class with the Palm organizer or the g-2 coils? Only this: it encourages us to look at this organisation of humans and things as an instrument craftily designed to perform specific functions in a stable and predictable manner. It is a well-ordered factory for the dependable production of correct answers to sums. So the WPA human calculator is no less a piece of technology and as much of an engineering achievement as the Palm or the g-2 coils. We might say that the WPA human calculator could pass an ironic Turing Test for being a machine.

However, the process of designing with nonhuman components is a different kettle of fish from designing with human components. This has to do with how designers can impose stability and predictability on the different kinds of entities. A first-order distinction would be to say that nonhuman entities must be disciplined by means of Baconian ruses, i.e., by mobilising natural law, while human entities must be disciplined by Benthamite panopticism, i.e., by surveillance and the judicious application of the carrot and the stick. The point is that entities subject to natural law can be disciplined (made stable and predictable) by embedding them in the right material configurations – at least as far as our knowledge and insight reach. Human entities must be convinced, cajoled, and coerced to impose self-discipline, inasmuch as it is impossible to control or predict movements, let alone thoughts, in sufficient detail to guarantee useful and predictable performances. As with Taylor's famous 2-dollar-a-day man, the human entity has to be made to *want* to perform to rule. Engineers burdened with the design of large hybrid technological systems like urban water supplies and electricity systems are constantly faced with the problem of having to convince users to behave according to the dictates of the artifact-system as a whole.

The WPA Mathematical Tables Project shows that in a pragmatic sense, humans cannot simply be defined as agents. They can rather easily be made into components of artifacts – as indeed the history of industrialisation amply attests. These artifacts act, but not according to the will of the human components, but – if all goes "well" – as projections of the interests of their designers and masters.

### *Enschede: the explosion of S.E. Fireworks*

On the afternoon of May 13, 2000, a hot and sunny day, a series of explosions ravaged the neighbourhood of Roombeek in the northern part of the Dutch city of Enschede. The culprit was a fireworks storage and assembly facility called S.E. Fireworks. A fire on the grounds had somehow ignited explosives stored in a set of reinforced concrete bunkers; the ensuing blasts ripped the bunkers apart, shelling the surrounding area with chunks of reinforced concrete and igniting countless secondary blazes. In the space of 15 minutes the neighbourhood was reduced to smoldering ruins. Amazingly, only 20 people were killed, though many more were injured. Property damage was extensive.

S.E. Firework's highly visible and dramatic activity on that Saturday afternoon stood in stark contrast to its prior "behaviour". Somehow, the normal peaceful routine had broken down, and what we might call a "catastrophic deconstruction" of the facility and its immediate environment ensued. We have come full circle from the Palm parable to consider another artifact-in-use. But now, instead of an artifact working-to-rule, we have a disaster whose short-term effects seem to have left little room for "user interpretations". What can this "accident" teach us about humans, nonhumans and the dialectic of agency and structure; in short, about technology and sociology?

The leading question is whether we should see S.E. Fireworks as an agent or as a structure and, *ipso facto*, whether we should see the disaster as an eruption of agency or as a collapse of structure. Secondly, though primarily, we should sort out what kind of agency/structure we are dealing with. Are we talking about human organisation, about reflexive human agency, about a technical system and its associated failure modes? In short, how ought we to describe S.E. Fireworks, and how ought we to explain the explosion?

Let us start by noting that, until the moment of the explosions, the residents of Roombeek considered S.E. Fireworks as just another unremarkable small-scale industrial facility on the edge of the local industrial park. Few even knew that there were fireworks stored there. The municipality was of course informed and exercised its statutory right to perform periodic inspections and to provide permits for what was most certainly – and certainly in retrospect – a hazardous activity. It seems that to the extent Roombeek residents knew what was going on at S.E. Fireworks, their perceptions of fireworks as harmless entertainment and their trust in the city to enforce the necessary safety regulations suppressed any overt concerns. Testimony after the explosion corroborates this.

What kind of entity was S.E. Fireworks before the explosions? It was clearly what sociologists call an organisation, i.e., a *structure* of more or less well-defined role sets with incumbents more or less performing to rule (Crozier 1977). Presumably, there was more slippage in role performance in the routinised structure of S.E. Fireworks than in our earlier example of the panoptical WPA Mathematical Tables Project, but in essence they were similar entities.[6] On the other hand, S.E. Fireworks was also an "agent," even in its predisaster days. It was a legal entity one could call on the phone, make deals with, inspect, grant permits, and assign responsibilities. It was a significant player in the specialised custom-fireworks market. This double identity is hardly surprising, in fact, it is inherent in being an agent, inasmuch as agency (of whatever kind) presupposes a structured actor. The agent (or actor/actant) is always also a structure composed of sub-entities, and it is in fact by dint of analysis of that structure that the potentials for agency may be assessed. Classical psychoanalysis has exactly the same kind of deconstructive ambition with regard to the structure of human agents – in effect, postulating a structure of sub-agents like the id, ego, and superego that performs the aggregate agency of the person.

This ambiguity about agency and structure is not a problem because it does not compromise the agency-structure dialectic as an analytic scheme for tying together order and change and past, present and future. Agency and structure remain different although mutually constitutive aspects of entities. The difference is simply a matter of different levels of analysis and aggregation.[7] What *is* worrisome, however, is that sociologists persist in excluding technology from this dialectic – especially considering the explosive potential of some technology-rich organisations.[8]

The mutual implication of agency and structure and the exclusion of technology from sociological accounts holds *a fortiori* for the explosions themselves. Again, at a certain level of analysis, for example if we are concerned about the effects of the explosions on the physical, social, or political environment of S.E. Fireworks, we can black-box the structural complexities of the facility and treat it as a singular agent – albeit an agent gone beserk. However, if we are interested in the causes of the catastrophe, for example because we want to assign responsibility in connection with political and legal claims, then we shall have to unpack the structure of the facility (and perhaps the history of its facilitations by other actors). In particular, we shall have to focus on the constitutive actors/actants whose orderly and ordinary interactions constituted S.E. Fireworks as a (quasi)-stable enterprise. Clearly something out of the ordinary must have triggered the catastrophic breakdown of structure which transformed S.E. Fireworks into a raging monster. How do we go about describing this deviation from normalcy and its catastrophic consequences? Two hermetic idioms, "natural law" explanations and sociological explanations, are at our disposal.

Adherents of "natural law" would say that certain chemicals stored inside of concrete bunkers and sea containers caught fire and that as a result an explosion ensued that caused large chunks of the bunkers and containers to pepper the surrounding neighbourhood. Regarding this account we have, sociologically speaking, very little to explain. We could elaborate our "natural law" explanation, invoking chemical and physical theory to explain the causes of the explosion and the pattern of destruction that ensued. The points of departure are the physical properties of the materials, their disposition on May 13, 2000, and the presence of fire on the grounds of S.E. Fireworks.

A sociological explanation would argue that because certain employees were not being alert (maybe because it was very warm weather), because the company was forcing them to violate safety regulations or because the division of labour was such as to encourage miscommunication and accidents, a destructive explosion ensued. Here, we certainly have some sociological explaining to do. But we would miss the physical causalities involved in the explosion and hence, somehow lose the specific technological dimension of the accident – except to note that the failure of human discipline was contingently attached to highly destructive natural forces.

In practice, we see both kinds of discourses being used to deconstruct or "reconstruct" accidents like this. There is a well-developed discourse of technological risk which concentrates on the physical etiology (what sequence of events must have taken place in order for such an accident to occur) and which may point to human error as a contributory factor. There is also a discourse derived from organisational sociology which combines this approach with a focus on the human and organisational sources of such accidents (Perrow 1984). Here we can begin to see the humans and the non-living components as part of a single sociotechnical gestalt – as a technological-organisational hybrid with an innate proclivity to malfunction which is almost as "normal" as its proclivity to perform as planned. Diane Vaughan has demonstrated the strength of this approach in her analysis of the Challenger Space Shuttle explosion (Vaughan 1996). This is a promising avenue of approach because it understands technology as nature-made-social, as immanently composed of both non-living and human elements. It is a style of analysis which points the way to understanding S.E. Fireworks not as an ontological dichotomy, i.e., a physical structure on the one hand, and a human organisation on the other, but as a "hybrid artifact" consisting of patterned interactions between both non-living and human elements. What we require in order to analyse the explosion socio-technically is to be able to speak of non-human elements-in-use. We may need to have recourse to naturalistic explanations, but only as links in a chain of reasoning which inevitably also includes human intentions and (dis)order. The work of Perrow et al. clearly points to a sociology of technological culpability.

But if we want to speak of S.E. Fireworks as a latent agent that sprang into action on May 13, 2000 (or for that matter, as an apparently stable structure that deteriorated catastrophically on that date), then we still need to qualify the notion of agency involved here. Except at a formal level, i.e., in regard to the schemata of structuration referred to in the introduction, the agency of non-humans has a different logic than the agency of humans. Callon and Law, for example, argue for a differentiated notion of agency for different kinds of what they call "hybrid collectifs":

> ...translation does not have to take the form of language. For here is the bias, the logocentric bias which runs everywhere through social theory. The bias in favour of the speakable. ... Which is why, though we cannot, to be sure, say very much about it, we do not wish to link a notion of agency to linguistic re-presentation. For signification ... is more general than talk. It comes in all kinds of forms. And some, though only some, we can imagine. Others, no doubt, we will never know. Which means that there are multiform kinds of agency: forms of agency that we can't imagine; forms of agency performed in patterns of translation that are foreign to us; forms of agency that are, for instance, nonstrategic, distributed, and decentred. (Callon and Law 1995, 503)

Though Callon and Law might well reject this solution, we have considered the possibility of qualifying the agency of nonhumans as agency subject to "natural law", e.g., the laws of physics or chemistry. However, S.E. Fireworks was not merely composed of nonhuman beings; it was a "hybrid collectif" in which humans and nonhumans were intimately juxtaposed and mutually transforming. Its agency was thus amenable only to explanations which somehow combine "natural law" and classical sociological explanations. This is the challenge, not only for scholars of technology, but also for commissions investigating the "causes" of such disasters.

### *What is technology?*

Our four parables have given us important insights into technology. These can be summarised as follows:

1 The user testimonials about Palm organizers question the simple notion of the artifact-as-tool and hence of the actor as unproblematic tool-user. The

simple notion of a tool is: an artifact that an intentional subject uses to get a specific job done. There are several points that need elucidation: How must the Palm be shaped and disciplined in order to use it? What self-discipline must the subject impose on him or herself in order to be able to use the Palm as a tool at all? How does the Palm discipline the thoughts and movements of the user? In what sense do the user and the Palm compose a cyborg, i.e., in what ways do the Palm and the human user become a single hybrid actor?

2 The high-energy physics story reminds us that technology is not only a set of material structures that we live with and that transform us, but that they are intelligently and purposively designed to perform particular functions vis-à-vis agency and social order. This does not imply that the intended design completely maps the design in use. Maximising this mapping is a major problem for designers, developers, and (sometimes, as in this case) users. The design process is therefore contended and negotiated and thus constitutes an authentic field for sociological study.

3 The story of the "human calculators", i.e., humans organised and disciplined by means of panoptical and Taylorist methods to do calculations for making mathematical reference tables, argues that the stuff of which artifacts are made makes no principled difference to defining and using them as means – even if, as in this case, that matter is human brains and bodies. The inverse point is that the presence of human brains and bodies does not necessarily imply the presence of human subjectivity, e.g., free will, imagination, spontaneity, etc.

4 The S.E. Fireworks story makes two new points and also recapitulates lessons from the other three stories. The new points are, first, that agents are also structures and, symmetrically, structures are also agents. The distinction rests on levels of analysis. Almost as a corollary, it follows that a breakdown of socio-technical structure can be analysed as agency of the structure vis-à-vis its context (of other structure). Points from the other stories are recapitulated as follows:

– S.E. Fireworks, in both its stable and unstable manifestations, was a "hybrid collectif" just like the "cyborg" Palm+user.
– Like the WPA Mathematical Tables Project, S.E. Fireworks incorporated human actors as stabilised ("translated") entities of its process. These were also implicated in the structural breakdown.
– S.E. Fireworks, like the muon g-2 coils and indeed artifacts in general, was a constructed "hybrid collectif" for whose behaviour and misbehaviour the designers and maintainers share responsibility.

## Conceiving a sociology of technology

How can this Protean phenomenon called technology be incorporated into mainstream social theory? The field of Science and Technology Studies has by and large set itself up as an alternative, rather than a corrective, to the classical sociological canon. Symmetrically, there is still little interest within mainstream social theory for the accomplishments of the new technology studies, in spite of the evident impacts of new technologies.

There are a few ridge-riders, however, who are claiming that classical social theory and technology studies have mirror-image strengths and weaknesses, and would profit from a synthesis. Where classical social theory is able to conceptualise large-scale changes in the historical landscape and has a vigorous sense of structural constraint, technology studies seem limited to contingent and local explanations of mere episodes. Conversely, where technology studies have developed subtle methods of understanding technologies, classical social theory is still at sea when it comes to thinking about the technological dimensions of social order and transformation. Hence, these authors argue, there seems every reason to try to formulate some kind of synthesis not based on an a priori rejection of classical sociology. We shall take a look at three of these efforts.

### *The perspective of the user*

Mark Shields argues that sociological efforts to comprehend technology – including the new technology studies – are all in thrall to what he terms an "instrumentalist" conception of technology. "Instrumentalism" for Shields means understanding technologies as "purposive instrumentalities whose relevant explanatory properties may be described exhaustively within a framework of means-ends rationality" (Shields 1997, 190). Because of this "instrumentalist" perspective, which positions technology in a sphere of rational, pre-social phenomena, classical sociology tends to ignore technology. Weber's disdain of means-ends rationality as the "degree zero" of social action, no less than Pareto's distinction between logical and non-logical action, has encouraged sociologists to cede technology to the sphere of science and economics. Marx, of course, also saw technology as primarily a product of economic calculation, as machines whose forms were shaped by the exploitative ambitions of competing capitalists. Ironically, Shields argues that even the new technology studies – however salutary their redefinition of technology as an inherently sociological phenomenon – do not escape this instrumentalist horizon. Even here, technologies are seen as products of instrumental design, of efforts to produce specific use-values for specific social groups.

According to Shields, the way out of the instrumentalist trap is to look at technologies in use. The social meaning of a technology is not what its designers claim it to be, but in what *users* make of it. Shields formulates this as a principle of "instrumental underdetermination", as a failure of instrumentalist intentionality to exhaust the social meaning of a technology. Shields, in fact, seems to be arguing that the sociology of technology only properly begins at the point where users take over from designers to integrate artifacts into what he calls "sociotechnical practices". "Technological artifacts are thus polysemic, because different agents – inventors, designers and users – employ schemas, or 'frames of meaning' ... that render artifacts 'capable of being interpreted in varying ways'". A variety of agents, working with different perspectives, constitute "sociotechnical practices" around specific artifacts or technological systems and provide the proper subject matter for the sociology of technology.

Quite aside from the question of whether Shields' characterisation of new technology studies as essentially instrumentalist is apposite – which I think it is not – the overall point is well taken. Clearly, when we focus on technologies-in-use instead of only on technologies-as-instrument (as material means for attaining specific ends), we uncover a rich sociological and anthropological dimension to technology which, moreover, can be approached with traditional theories and methods. On this view, technologies are not some non-social bit of logical action, but become societal constructs, just like laws, religions, norms and the other furnishings of classical sociological theory. Technologies, in this sense, become sociological objects in an immanent and transparent way and are no longer sociologically inexplicable intrusions into the social from some other realm.

However, Shields's rejection of "instrumentalism" throws out the baby with the bathwater. There is a difference between asserting that technology is *only* an instrument, and asserting that it is that, but also many other things as well. I think Shields fails to make this distinction and in a shortcut effort to redefine technology as sociologically "just folks" wrongly quarantines the instrumentality, which makes technology such a unique and pervasive sociological phenomenon. The g-2 coil story – which, in spite of its exotic context, seems to me on this point perfectly generalizable to all kinds of other technologies – makes quite clear that artifacts are designed as "purposive instrumentalities". In design, as Bucciarelli (1994), Henderson (1999) and Vincenti (1990) make plain, artifacts-in-becoming are, as Shields puts it: "described exhaustively within a framework of means-ends rationality". That is indeed the business and logic of design. The question then is: what is the relation of design as a specific subset of societal practices to the ultimate working of artifacts in society?

It is true, as Shields argues, that design suffers from "instrumental underdetermination". Its instrumentalist horizons do not indeed exhaust the possibilities of artifacts-in-use. However, "instrumental underdetermination" is not an argument for the irrelevance of design, nor for the irrelevance of a sociology of design. It is only a powerful argument for also including actual "sociotechnical practices" in our perusal of technologies.

Although there is unquestionably some slippage between designed artifacts and used artifacts, this is certainly a question of degree and differs according to the type of artifact. While a knife may be designed as a weapon, it can also cut bread. The Palm Organizer, designed as an electronic appointment book with note-taking facilities, has been seized upon by users and programmers and endowed with a plethora of non-intended uses and identities. The g-2 coils, on the other hand, are such complex and dedicated pieces of equipment it is hard to imagine another use which exploits their essential design features than the one for which they were in fact designed.[9] It is also not easy to imagine that the ultimate users will develop significantly different operational protocols from those developed in the design phase. This suggests two untested and speculative first approximations about the relationship between design intentions and ultimate use: First, the complexity of an artifact is something like inversely proportional to its flexibility-in-use. Second, the more context-bound an artifact, the less likely actual use will deviate from the use envisioned by designers. These propositions want testing, but even in this tentative form they suggest that care should be taken in divorcing uses (and effects) observed in practice from uses previously envisioned in design.

In general, a principle of "limited flexibility" seems apposite, stating that the way artifacts are designed is more or less consequential for the way they will ultimately be used. Products may in fact be specifically designed with what might be called a "topography of use", i.e., gradients encouraging and discouraging particular uses. Users can sometimes get around such design topographies, but if the designers are on the ball, only at costs which may in fact be disheartening.

### *Having the post-modernist cake*

Fran Collyer (1997) is not so worried about "instrumentalist" biases in technology studies. Nor does she advocate a new focus on technology-in-use as a remedy. At another level, however, she shares Shields's concerns of how to merge "post-modernist" theories of innovation associated with authors like Callon, Pinch, Bijker, Latour, and Hughes, with more generic social theory. As she puts it:

> Although post-modern perspectives have correctly identified the emergence of a greater diversity in social relations and broken down the distinction between subject and object, post-modernism is too often considered in terms of a total replacement for structuralist sociology. In its stead, it is suggested that the insights of post-modernist theory be added to the sociological 'armory'. Such a merger would allow a better integration of theories of technology and society. This would produce a more adequate theory of invention and help to explain how social inequalities shape the invention process. (Collyer 1997, 203)

To achieve this merger, it is essential that post-modern theory abandon its posture of splendid isolation. Moreover, it contains a number of flaws which must be remedied before it can be "added to the sociological 'armory'".

Collyer seizes upon Callon's "translation networks" as the paradigm to be criticised (Callon 1991). The first problem is that the model "offers insufficient explanations for the relationship between the actants or the differing capacities of the actants to direct and control the invention process.... the actions of some actants (such as an individual or group) are both quantitatively and qualitatively different from the actions of other actants (such as a computer or an amoeba)" (Collyer 1997, 199-200).

This lack of what we might call sociological relief of course inheres in the notion of "actant". The whole point of the concept is to denote a relative or momentary "phase state" of an entity: that which in a given situation is initiating a transfer of "intermediaries" (instead of itself being transferred). So the notion of "actant" has no essentialist connotations. It is only a role in the network dynamics which every entity (human or non-sentient) can at times play. We have seen in the case of S.E. Fireworks that the explosives were transformed from intermediaries into very forceful actants, and in the case of the WPA Mathematical Tables Project that the human calculators, agents all, were reduced to "mere" intermediaries. However, from a traditional sociological perspective this structuralist focus on network dynamics at the expense of ontological veracity is, as I argued above, immensely unsettling, and Collyer's criticism here is directed at just that point.

From the point of view of an adequate sociology, it would be desirable to have some indication of the relative chances of different kinds of entities (e.g., humans or non-sentients) of becoming either actants or intermediaries. We would also want to know how different types of entities change phase, i.e., change from actant to intermediary and vice versa. What types of processes involving what types of other entities typically induce this transformation for different kinds of entities? In the context of the S.E. Fireworks story, for example, I argued for a distinction between natural and human causality. Finally, what types of entities tend to be dominant in translation networks? Sociology has developed a vast conceptual arsenal for dealing with power relations and "life chances" among networked human actors; is anything like this possible when non-human or non-sentient actants get involved? Is there, to echo Marx, anything determinate in the final instance? Do the oysters, or do the walrus and the carpenter, typically carry the day? Or can we, like the carpenter, take stock only *after* the oysters have been eaten up?

Collyer also takes translation network theory to task on another count. She criticises it for what we might call its solipsism, i.e., its tendency to discount an external world. The focus is on the internal process. External "factors", limits and opportunities are simply not taken into account. Collyer says: "Theoretical disregard for the consequences of social structure means that the model over-estimates the capacity of scientists and others within the network to shape their own circumstances just as it under-estimates the impact of societal processes beyond the immediate activity of the actors" (Collyer 1997, 201).

This is a sociologically unexceptionable criticism. However, it does not absolve us from defining just what we mean by this "social structure" and explaining how it impinges on the ongoing structuration of the translation network under consideration. If the narrative strategy of Latour's *Aramis* is any clue, then the network approach solves the problem simply by subsuming all elements that have some bearing on the unfolding plot of the translation network into the network itself (Latour 1996[e]). Hence, there literally is no external "social structure" or, rather, elements of that putative "social structure" are absorbed into the network as needed (both by the actants and the analysts). The network simply expands to cover the relevant turf. However, such rampant contingency literally robs us of a coherent vision of the social world and obviates the possibility of prediction and the hope for societal management of technological development.

But then, what *is* "social structure"? In one sense, it is only a bookkeeping ploy to distinguish what is transient and of immanent pragmatic or analytical interest from that which is more stable and lasting – and which is taken for granted as a background of available "rules and resources" (Giddens 1984) by both actors and analysts. And, in a historical sense, structure is a residue of agency. Factors, institutions and positions are built up over time and can persist thanks to the benefits they produce for the few or the many. These structures define cost-benefit gradients for different types of actor-strategies and thus shape dynamic social processes.

### *New rules for a sociology of technology*

What clearly has to be done if the "merger" between "post-modern" theories of technology and sociology is to have a chance to align these two discourses in some way. Werner Rammert (1997), our final ridge-rider, has made just such an effort in the form of a new set of "New Rules of Sociological Method".

Rammert's twelve rules, a double-take on Anthony Giddens's (1993)take on Durkheim, are an attempt to define a general sociology capable of incorporating technology as a "social fact". Rammert's specific aim is to combine "a constructivist explanation of technology generation on the local level ... with a social evolutionary approach of structural selection on the global level" (Rammert 1997, 171). Like Collyer, Rammert criticises the new technology studies for their inability to comprehend large-scale structural processes. He shares Giddens's view that a rational sociology must "chart a course between interactionism and structuralism" (Rammert 1997, 173) and so he seeks to complement the "interactionism" of SCOT (Bijker and Pinch 1987) and actor-network theory with a "structuralist" mode of analysis. Rammert begins by defining what he sees as the essential sociological nature of artifacts. His first three rules reconfirm basic conclusions we drew from our technology parables, particularly the dual agent/structure nature of artifacts and the importance of design in establishing artifact properties and societal effects.

Rules 4 through 7 address possibilities for a sociological account of technology development. We are up a notch from the design floor. The argument turns on the concept of "technology projects". These are concerted efforts to combine inquiry into the unknown with routine resources in order to produce "an artificial and reliable technical system" (Rammert 1997, 180). The elements of such a "technical system" can be "physical effects, material artifacts, sign codes and habitualised routines". But note, not human bodies. Technical projects are theatres of social conflict and co-operation; a plethora of heterogeneous actors with different resources and following different rules do battle in order to project their own notions of order and utility onto the project in becoming.

Rules 8 and 9 take us a step further on the ladder of socio-technical aggregation. Rule 8 suggests ways of conceptually bridging the gap between local and idiosyncratic technological projects and the various "institutional fields" of society. If local projects aim at the constitution of a successful techno-structure (the context within which artifacts become operative), then this can only be achieved on the basis of "micro-politics of negotiation" between local actors and the macro-social networks. Rammert distinguishes four "fields": the scientific, the technological, the political and the economic. Science is about whether proposed operating principles are feasible. Technology is about defining standard procedures and acceptable interpretations of the "state of the art". Politics is about the ideological and political resonance of projects. Which particular variants will politicians back, and what are the legal and funding consequences? Economics is about techno-structures in the context of innovation within firms.

Rules 10 and 11 represent an effort to tie the level of concrete local projects, as incremental additions to the stock of technology, to the overall dynamic of technology at a global level. Rammert argues that on a global level the structuration process should be treated as "blind variation" because techno-projects are blind to long-term effects and have all kinds of "unintended consequences" anyway. Local activities of enrollment and translation in actor-networks are not undertaken with an eye to overall outcomes. They could not do so even if they would, because of the various "structural filters" – conceived as institutionalised patterns of constraints and enablements – imposed by the different fields through which technology projects must navigate. "... the operating filters are manifold, their effects cannot be precisely calculated, and ... they are developing simultaneously" (Rammert 1997, 184).

Rule 12 summarises Rammert's approach: "Technical change neither results from a structural logic of development that operates beyond the scope of social actors, as Durkheim's first rule may suggest, nor is it entirely open to voluntary action and various constructions of technology, as social constructivism may suggest" (Rammert 1997, 186). This general argument positions Rammert's rules squarely within structuration theory. Sociologically salient are all those mechanisms which encourage predictability and stability. As Rammert restates rule 12: "Structural filters which are institutionalised in the different fields of the innovations system reduce the *principled contingency* of technical change to certain *corridors* of technical development. But they maintain the status of stabilised technology only as long as social actors practically reproduce the techno-structures" (Rammert 1997, 187).

Rammert's overall effort merges core concepts from actor-network theory as articulated in the writings of Callon, Latour and Law, with Giddens's general theory of structuration. The keystone is the integration of different levels of analysis within the framework of an overall local-global dynamic. The local dynamics are contingent – as actor-network analyses keep stressing – even though – as Rammert stresses – they take place in the context of global structures of rules and resources, i.e., in the context of field-specific "institutional filters". So even with the contingent variety produced at local levels, there is already steering of technological "trajectories" due to the impinging of more or less stabilised institutional structures. In this way technology is from its inception a "social fact", i.e., a structure explainable by recourse to other "social facts". In the best traditions of structuration theory, Rammert argues that these local projects culminate in new techno-structures which subsequently become part of the institutional order defining and shaping new technological projects. Levels of analysis are joined in the transitions between rules 4 and 5, 7 and 8, and 9 and 10.

## Having the cake and eating it

This said, our modest technology stories, no less than Shields's and Collyer's texts, justify taking a second look at Rammert's solution. While his fine-grained proposal for joining classical sociology to the new technology studies seems a direct answer to Collyer's plea and is framed in the agency-structure dialectic suggested by our stories, there are still some worrisome points. In spite of Rammert's openness to "post-modern" technology studies, he does not offer quite the kind of solution Collyer seems to have in mind. Rammert gives a wide berth to just those "post-modern" elements of new technology studies that Collyer finds most intriguing. Likewise, Rammert's text is a red flag from the perspective of Shields's diatribe against "instrumentalism", despite Rammert's explicit rejection of an "instrumentalist" approach in favour of a "pragmatic" one (rule 3). Rammert's overall approach to technology is to view it as a societal problem-solving strategy centred on the design of artifacts. In so doing, he pays little attention to artifacts-in-use, although his framework does provide the necessary conceptual space. Insofar as use or users figure in Rammert's sociology of technology, it is all about representations by designers of such use: i.e., the "configured user" rather than the empirical patterns of use themselves.

Our technology stories concur in identifying these as serious gaps. A competent sociology of technology must encompass both the design of technologies and their societal implementation, or "use". Rammert's neglect of the latter aspect makes it easier for him to merge technology studies into traditional sociology. By concentrating on design, rather than use, Rammert can avoid the debate about the agency of nonhumans. Design is about the *structuration* of artifacts, i.e., about conceiving and building "techno-structures", a process in which artifacts are object, rather than subject, of agency. As Collyer suggests, the doctrine of nonhuman agency is the most radical attack possible on sociology as a modernist project. Rammert's focus avoids messing with traditional sociological ontologies; this is apparently the price he thinks he must pay to remain sociologically credible. In point of fact, he explicitly distances himself from what he calls "some exaggerations" of the actor-network position for their refusal to distinguish between "reflexive human agents and non-reflexive non-human agents" (Rammert 1997, 186).

So Rammert still leaves us with two knotty issues: how to sociologise technologies-in-use and how to conceptualise the agency of artifacts. On the basis of what has been said above, it should be possible in principle to distinguish a sociology of technology-in-use from a sociology of technology-in-design, although rarely will we be able to distinguish these as separate phases in practice. Our stories attest that all kinds of ironic and unintended effects can erupt when once-designed technologies are put to use, some of which will be quite oblique to the interests which framed the original design of the techno-structure itself. As noted, artifacts may have certain use-gradients "designed into" them, but they are far from impervious to redefinition, "misuse", or catastrophic failure when put to work in context (Fleck 1999).

As Shields argues, the "context of use" should not be seen merely as a sphere in which the artifact "ripens" as a "techno-structure", i.e., in which the potentials of the artifact are revealed in practice. It is at the same time a sphere in which the techno-structure reveals the potentialities it has for restructuring the societal context into which it has been introduced. The point is that the social context of use is modified or "evolves" in the very same process in which the artifact itself is modified and in which it evolves in new directions. This is part of the meaning of the "co-evolution" of technology and society. S.E. Fireworks was a dramatic example, but the Palm organizer and its fellow travellers will no doubt be more consequential in the long run. A sociology of technology-in-use would do well to follow Rammert's and Fleck's lead in distinguishing local, contingent contexts of use from more global structural and institutional contexts.

To my mind, there is little in Rammert's text to suggest that he would disagree with any of these points. The problem seems rather a matter of emphasis than the willful and thematic suppression of technology-in-use. Rammert's focus is on technology dynamics, the fountainhead and until recently the working face of new technology studies. Hence he elaborates on how criteria for new technology are established and on how resources for constituting new technologies are assembled, rather than on the *effects* artifacts and technological systems have on societal order, as modifications of agency and as new elements in the structural landscape. However, nothing suggests that

Rammert is principally insensitive to these issues, and more importantly, there is nothing in his proposal that would militate against including technologies-in-use as an integral "phase" in the technological dialectic he proposes. A similar local-global logic would be apposite here, with locally contextualised usages generating varieties of experience and critique which would be differentially institutionalised depending on their resonance with different "institutional filters". The use of technologies and the transformations of agency and structure which that entails could be seen as a form of informal societal innovation subject to the same kinds of dynamics as the more formal innovation in institutionalised design settings Rammert now seems to be focussing on.

The agency of nonhumans is more difficult to incorporate into Rammert's new synthesis. He himself seems adamant in reserving agency to human persons, coupling agency irrevocably to "reflexivity". This is of course the classical sociological prohibition, and the question is just how forbidding is it? Does it in the end prevent us from realising Collyer's project of integrating classical sociology and "post-modern" technology studies?

I have already suggested that introducing nonhuman entities and heterogeneous types of agency does not compromise the dialectic of agency and structure as a sociological mode of reasoning and explanation. That is to say, deviant (*in casu* nonhuman) forms of agency do not compromise the dialectical core of classical sociology. What *is* compromised, however, is the classical logic of attribution, of explanation of actor behaviour as canonised in Max Weber's famous dictum of *Verstehen*. Without such possibilities for attribution, sociology is at sea; actors must be invested with valences, preferences, interests, etc. in order for their behaviour to be sociologically comprehensible, i.e., to be *soziales Handeln* in Weber's sense. Or must they?

In point of fact, it is my impression – though I can hardly prove it in the scope of this chapter – that sociology really has no deep or consistent definition of the *homo sociologicus*.[10] From sociology's inception, the inner workings of human actors, by all accounts the constitutive elements of social order, have been black-boxed in order to throw up ramparts against the seductions of reductionism. Sociology's project is in a sense to deny human agency a reality *sui generis*. To put it very crudely: society is all; individuals are nothing. It is true that some 20th-century American strains of sociology like symbolic interactionism, ethnomethodology, or Erving Goffman's "dramaturgy" have made an effort to flesh out a concept of human action, underscoring its creative, dramaturgical and interpretative features. These interpretative traditions define human actors as the makers and sustainers of social order and devote much attention to describing how local settings are produced by the ongoing creative agency of human participants. But this is a "little tradition" in the sociological project, in its approach and marginality analogous to social constructivist theories of technology. Like the latter (as Rammert rightly argues), there is a big gap between explanations stressing creative agency and local contingency and those aiming at the clarification of global structures as constraints on and resources for local agency. In this "big tradition", human agency is consistently schematised. Humans are treated more or less either as mechanical input-output devices (rational action theory), as bearers of sets of interests (class or otherwise) and "value dispositions", or as complex self-constituting monads whose perceptions and motives in any given situation must be intuited by the analyst (i.e., *Verstehen*). All of these approaches impute arbitary dispositions to actors, making them available as narcissistic alter-egos of the sociologist. Hence, the rejection of nonhuman agency by classical sociology (and by Rammert in its wake) does not appear to be justified by the wish to preserve a deep and rich theory of human agency, but rather by its opposite, the fear of having to provide such a theory.

In a way this is an opportunity, rather than a liability. *Pace* Herman Hesse, we do not have to begin by first destroying a world. However, in order to exploit the opportunity, we have to avoid a certain *idée fixe* which has paralysed debates about admissible forms of agency. This is the notion that we have to define nonhuman agency as a sociological category. If our technology stories show anything at all about agency in a material world, it is that it is never either purely human or purely nonhuman, but intrinsically *heterogeneous and hybrid*. Agency is not, to be somewhat precipitous, rooted in the properties of entities-in-themselves, but rather in the properties of entities as elements of networks (or structures). And those networks/structures are invariably concatenations of both human and nonhuman actors.[11]

The idea of the actor-network encourages us to think in terms of distributed agency rather than the agency of discrete entities. In the S.E. Fireworks story, the bunkers and the explosives certainly acted, but they did not act alone, nor did they do so in isolation from human actors. The entire "hybrid collectif" of S.E. Fireworks is the agent of destruction here, not one or another human manager, operative or technical component. Arie Rip happens to live close to the site of the explosion. The concrete projectile which impacted in his back yard and pulverised several bricks there is no doubt an actor in respect to the previous structure of that bit of his back yard. However, it only became the actor it did by virtue of its former place in the hybrid socio-technical actor-network of S.E. Fireworks: a network, as it turned out, that consisted of an explosive mixture of unreliable humans and unreliable nonhumans implicated in complex agency-structure dynamics, i.e., in complex chains of mutual translation.

It is the dynamics of such concatenations, i.e., Callon and Law's "hybrid *collectifs*", that have to be incorporated into the socio-logics of agency and structure, rather than nonhuman agency *per se.* This is of course a metaphysically daunting task, inasmuch as heterogeneous chains of agency and causality are implicated. It is a task that Rammert has neither attempted nor even defined as worthwhile – and I would say to the detriment of his otherwise admirable project. There are, however, promising leads. Marx's analysis of the machine is certainly one of them (MacKenzie 1984), with the tradition of labour-process theory in its wake (Noble 1984, Kern and Schuman 1970). More recently, Perrow's already cited work on "normal accidents" has given us fine-grained accounts of the behaviour of risk-ridden "hybrid *collectifs*" which could be extended to less accident-prone organisations and networks. Of course, actor-network theory has been the programmatic guiding light in regard to mixing metaphors (and actants). However, it is flawed by its preference for metaphysics in favour of history (i.e., sedimented structure) and by its polemical advocacy of the identity – rather than the sociological equivalence – of human and nonhuman agency. What we now need is an extension of Rammert's project which retains his commitment to the socio-logic of agency and structure, but which also incorporates the mixed ontology of the "hybrid *collectif*".

## Notes

1 For an example of this mutual estrangement, see the recent exchange between Bruno Latour (1999[c]) and David Bloor (1999[a], 1999[b]).

2 www.palm.com

3 g-2 coil-group minutes. February 12, 1987.

4 g-2 notes 007, minutes March 26, 1987, joint meeting.

5 g-2 notes 007, coil group meeting June 19, 1987.

6 Analysts from the actor-network school would assent to the tenor of this picture, although they would refer to processes of "stabilisation" and "irreversabilisation" rather than speak of a substantive structure or organisation. They would also, unlike sociologists, grant nonhumans their proper due in the actor-network.

7 Actor-network theory, set up as a technologically sensitive theoretical rival to sociology, also replicates this sociology of levels (Elias 1978) using concepts like "point-representation" and "macro-actor" (Callon and Latour 1981).

8 A major exception must be made for the tradition launched by Charles Perrow to which I will return below. See Perrow (1984) and Vaughan (1996).

9 In fact, in 2003, several new experiments were proposed (and will presumably be

carried out) which utilise the generic capacity of the detector as a storage ring for muons. So even in this dedicated design there appears to be enough ambiguity to allow for different socio-technical practices-in-use.

10 See Boudon (1974) for an agonistic example of the struggle to define – and not to define – who or what the sociological actor is. The struggle is instructive because it is an explicit attempt to define the "rational kernel" of sociology on the basis of the synthesis of classical texts.

11 This position has a certain affinity with Barry Barnes's recent critique of the individualist bias in social theory (Barnes 2000), but with a difference. Barnes argues that the classical sociological tradition, including synthetic reformist theories like those of Talcott Parsons and Anthony Giddens, has been blighted by an undue stress on individualistic agency. This would seem to indicate for sociology an elaborated theory of human individuality, which ironically is lacking. Barnes concludes that the emphasis on human agency in recent social theory is a reaction to determinist sociologies. Agency boils down to the use of individual rationality to resist "irrational" societal "constraints". Human agents can be free because in the final analysis they are nobody's fool. Barnes argues that this individualistic approach, enshrined in Rational Action Theory, is misguided and that instead we should look for another kind of "collective agency" rooted in the essential sociality of human beings: "…the characteristic accomplishments of human beings are precisely the products of their lack of independence as responsible agents. Their cultures, institutions and forms of life; their inventions and innovations; their ability to generate and direct awesome concentrations of power; are all the result of their collective agency, which derives in turn from the the mutual susceptibility linked to their concern with face and status" (Barnes 2000, 143).
My argument that agency should not be situated in the properties of entities-in-themselves but in the networks they constitute with each other certainly resonates with this position in a formal sense, but I can see no self-evident way to map Barnes's conception of "mutual susceptibility" among humans onto the kinds of relationships prevailing between humans and nonhuman entities – let alone those among nonhuman entities themselves. If we succeed in theorising the agency of the "hybrid *collectif*" in a Barnesian vein, it will have to be by grafting the radically different logic of "natural law" (and its articulation with human agency) onto his humanist conception of mutual susceptibility "linked to concern with face and status". This would at the very least entail re-emphasising human rationality (as the capacity to understand and exploit behaviours subject to "natural law") as the basis of hybrid agency. As far as I can see, something like this would be the only route to incorporating nonhumans into Barnes's charmed circle of "collective agency".

# Artifacts as Social Agents

*Philip Brey*

## Introduction: The agency of artifacts

Do artifacts act? Should agency be assigned to them in accounts of social change? Or are human beings and social structures like groups and organisations the only social agents? This is a pivotal question for technology studies, but one that has not received an unequivocal answer so far. On the one hand, the literature in technology studies is filled with examples and cases that suggest that technological artifacts and systems do act: they have been claimed to prescribe behaviours, constrain political arrangements, induce cultural beliefs and practices, and shape aspects of their social context. On the other hand, the social constructivist orientation of a large part of technology studies seems to be incompatible with an attribution of agency to artifacts, because it maintains that alleged properties of artifacts can be reduced to the actions and interpretations of social groups.

There is general agreement in technology studies that the introduction and use of a new technology is often accompanied by significant changes in its social context. Such changes may include changes in individual and collective behaviours, attitudes and beliefs, in social statuses and roles, and in social structures and institutions. This generally accepted idea goes against the notion that technologies are neutral, in the sense that they are mere means-to-ends that function to perform certain tasks more quickly, efficiently or powerfully, and that a proper analysis of them focusses on their function as a means to chosen ends. It is a core belief of technology studies that technologies must also be understood, and perhaps centrally, as building blocks of society and as instigators of social change, in ways that are often unrelated to their intended functions.

But here the agreement stops. One may agree that the widespread use of the birth-control pill has been *accompanied by*, and can be *correlated with*, sexual liberation and greater freedom for women, and that *without* the pill these changes would not have occurred. But then one may go on to seriously disagree about the agentive role of the pill in this whole process. On the one hand, one may present a narrative in which the pill is a powerful actor, a hero (or villain) that single-handedly gave sexual freedom to generations of liberated women. In this epic, the pill may be depicted as a liberator, with sexual freedom written all over its chemical code. It only needed a chance to act. Yet, one may also tell a story in which sexual liberation is not created by a little pill, but by people who were already in the process of a revolution when a little chemical entered the scene, and which *made* it play an important role by attributing meanings to it and by involving it in real-life practices. In this story, there is no such thing as a pill with inherent liberating powers. The pill, as a catalyst for social change, is a social construction. Pills do not act; they are inherently powerless and amorphous. But people can make them look as if they have powers and agency by assigning interpretations to them and implicating them in practices.

These two perspectives characterise two of the three dominant perspectives in technology studies concerning the nature and status of technological artifacts and systems. They are the *realist perspective*, according to which artifacts have inherent properties and agency can be attributed to them in a straightforward way, and the *social constructivist perspective*, according to which artifacts do not have inherent properties but only imputed or attributed properties, and any imputed agency of them ultimately derives from the interpretations and behaviour of individuals and social groups.

Besides these two perspectives, there is a third, which I shall call the *hybrid perspective*, which has been taken up most forcefully in *actor-network theory* (Callon 1987; Latour 1987; Callon and Latour 1992). In this perspective, the neat distinction between the social and the technical or material, accepted by both realists and social constructivists, should be abolished, and artifacts and their properties should be analysed neither as objective facts nor as mere social constructions, but as *both* real and constructed. Artifacts and their properties emerge as the result of their being embedded in a network of human and nonhuman entities. It is in this context that they gain an identity and that properties can be attributed to them. Hence they are constructed. But since this network is not a purely social network (it includes nonhuman entities as well), they are not *socially* constructed. And since they are participants in the network as well, one can attribute agency to them, even though this agency derives from their place in the whole network.

In this essay, I shall critically evaluate these three dominant perspectives on the agency of artifacts. My conclusion will be that none of these perspectives provides a satisfactory account of the agency of artifacts, and I shall close by sketching an alternative perspective, which I call *differentiated constructivism.*

### Realism

Realists maintain that social change accompanying the use of a technology can often be causally correlated with the design structure of these technologies themselves, and that therefore these technologies can be properly analysed as possessing *powers* for effecting change, and that when these powers are exhibited, the technologies are properly analysed as *acting*. Moreover, the agency of artifacts is held to be irreducible to the agency of human agents involved in their production, regulation or use: it is a feature of artifacts themselves, just like your action of buying a sandwich is not reducible to the actions of others (although in many ways shaped by the society you live in).

There are many examples in the relevant literature that seem to support this realist position by showing how the design of a technology constrains or enables practices, beliefs, or social configurations. In all these cases, one is tempted to say that it is the technology that enables the occurrence of these practices, beliefs or configurations, and hence that the cited artifacts or systems have agency. Latour (1992), for one, discusses how mundane artifacts, like seatbelts and hotel keys, may prompt their users towards certain behaviour. A hotel key, for example, has a heavy weight attached to it in an attempt to encourage hotel guests to bring their key to the reception desk upon leaving their room. Sclove (1995) points out that modern sofas with two or three separate seat cushions define distinct personal spaces, and thus work to both respect and perpetuate modern Western culture's emphasis on individuality and privacy, this in contrast to Japanese futon sofa-beds, for example. Winner (1980) discusses nuclear power plants, which, he claims, require centralised, hierarchical managerial control for their proper operation. They cannot be safely run in an egalitarian manner, unlike, for example, solar energy technology. In this way, nuclear plants require that a particular form of social organisation be adopted for their operation.

Within a naive form of realism, which may be termed *technological essentialism*, technologies may have inherent powers that manifest themselves in any context of use. Technologies may be *inherently* authoritarian, democratic, unjust, deskilling, repressive, egalitarian, individualistic, masculine, Western, etc. Langdon Winner claimed that a technological essentialist position is correct for at least some technologies. He argued that some technologies are "inherently political" in that they have specific political consequences that will manifest themselves in any setting. The atom bomb, for example, is inherently political because "[a]s long as it exists at all, its lethal properties demand that it be controlled by a centralised, rigidly hierarchical chain of command closed to all influences that might make its workings unpredictable.

The internal social system of the bomb must be authoritarian; there is no other way" (Winner 1980, 34). Other cases of technological essentialism in the literature include Ivan Illich's (1973) distinction between convivial and anticonvivial or manipulatory tools, Lewis Mumford's (1964) distinction between democratic and authoritarian technology, and feminist analyses of technology as inherently masculine or inherently patriarchal (e.g., Corea et al. 1985; Mies 1987; Merchant 1980).

Technological essentialism tends to underestimate the interpretive flexibility of technology and is vulnerable to counterexamples which show that such technologies, when used in a different cultural or social context, may often exhibit properties that are thought to be incompatible with their claimed essence. A more sophisticated variety of realism, which I shall call *contextual realism*, is more sensitive to the context-relativity of the workings of many technologies. Contextual realism holds that artifacts may impose constraints on their environment that derive from their physical design properties, but also postulates that such constraints will often differ in different environments or settings. Take, for example, Winner's (1980) famous, if contested, case of the Long Island bridges.[1] Winner claimed that these bridges were built at a height of often no more than 9 feet (2.75 m), a height that prevented buses passing under them, hence effectively blocking access to Long Island by public transport. Because most blacks depended on public transport at the time these bridges were constructed, the bridges consequently worked to bar access to Long Island for many blacks. The relevant constraint imposed by these bridges is hence that blacks were largely excluded from accessing Long Island (especially its popular public parks).

In a contextual realist analysis of this case, it is a feature of the material design of these bridges (their construction at a height of 9 feet) that was responsible for the constraint these bridges imposed on their environment, *viz.* making it impossible for buses from New York to access Long Island, and thereby barring easy access to Long Island for most blacks. Clearly, being discriminatory against blacks is not an intrinsic property of bridges in general, nor specifically of bridges built at a height of 9 feet. In many conceivable settings, bridges with a height of 9 feet would not be discriminatory against blacks. For example, they would not be in settings where blacks are not economically disadvantaged or have alternative modes of public transportation available to them, or where buses are less than 9 feet high.

So although 9-foot-high bridges are not intrinsically discriminatory against blacks, they may become discriminatory in particular settings, particularly in situations in which they are placed in areas in which blacks (and not whites) use buses as their predominant mode of transport, in which these buses are more than 9 feet high, and in which blacks cannot easily switch to alternative modes of transport. The setting constituted by New York and Long Island in the 1960s constitutes this type of setting, and hence the 9-foot-bridges in them are discriminatory. This discriminatory character derives from the relation or "fit" between the physical design features of these bridges (i.e., their being built at a height of 9 feet) and their setting or context of use.[2]

Other cases discussed by Winner also fit a contextualist analysis. For example, he deals with pneumatic molding machines used at a 19th-century reaper manufacturing plant in Chicago. In that particular setting, these machines had the intended effect of breaking the union, which represented the skilled workers in the plant, because readers undermined the power of skilled workers as they could also be used by unskilled workers, an outcome that benefited the owner of the plant. Clearly, helping to break a union (or even of undermining the power of skilled workers) is only something pneumatic molding machines can do in particular settings, that is, in plants in capitalist societies in which skilled workers are united in unions.

If the agency of technologies is hence context-relative, as contextual realism claims it is, would it not be more proper to say that agency does not reside in the artifact but rather in the whole setting, that is, *the artifact plus (relevant aspects of) the context in which it is used*? Contextual realists would, I believe, say that the attribution of agency to the artifact alone is justified because the artifact functions as the *major independent variable.* That is, whereas the agency is also dependent on other variables that are found in the environment of the artifact, the artifact itself is most directly and specifically linked to the changes that occur. Thus, whereas the bridges over Long Island would not have discriminatory politics if blacks in New York were not economically disadvantaged, the immediate cause of their being barred is clearly not the economic politics of New York, but the construction of the bridges. Thus, it is the bridges that are discriminatory, even though they can only have the discriminatory politics they have because of various other contextual factors.

Realists emphasise the physical structure and operation of artifacts and correlate social change with this structure and these operations. By focussing on the physical design of artifacts, they play down the role of social factors in effecting change. Although social factors may play an auxiliary role in contextual realism (e.g., social factors that are responsible for the poverty of many blacks in New York, in the case of the Long Island bridges), they are usually assigned a mere background role. One type of social factor that is particularly played down in realist analyses is that of *social representation.* The social representation of artifacts is the process of constructing shared (i.e., social) representations of them and their properties. Such social representations determine to a significant extent how an artifact is perceived by individuals, the specific features (including functions and relations to other entities) that are recognised in it, the way in which these features are evaluated, the way in which the artifact is ultimately used, and the consequences that result from this use.

Consider, for example, pink baby clothes for girls. Such clothes do not just have the intended function of clothing the child, they also impose a gender constraint by perpetuating a gender stereotype: they symbolise femininity, along with associated traits like sweetness, cuteness, passivity, etc. In this way, they promote a gender stereotype and promote the treatment of the baby girl in accordance with this stereotype. A realist analysis of this gender constraint appears to be incorrect. Pink baby clothes do not somehow physically induce a gendered treatment of the baby girls who wear them. It is rather the widely accepted social representation of pink as symbolising femininity and stereotypical female qualities that generates this particular treatment. The colour pink does not wear this symbolic meaning on its sleeve. In contrast, this gendered social representation of pink is a social construction that only exists in certain societies.

Another example, discussed in Pfaffenberger (1992), is that of the Victorian hallway bench, used in the hallway of Victorian houses to seat servants and tradesmen while they waited. The bench itself was plain and uncomfortable, without upholstery, whereas the hallway often included an ornate mirror and delicately carved hat hooks. The bench served to mark social status: it reminded servants of their inferior status, while also underscoring the superior status of the master, through the mirror and hat hooks below which the servants were seated. Here, again, the hardness of the bench and the ornateness of the mirror and hat hooks do not somehow physically require the persons who are seated on them to have inferior status, or the owner of them to have superior status. It is rather that social representations existed of higher and lower social statuses, including representations of attributes that were considered "fitting" for the specific class in question. It was considered "fitting" for the lower classes to make use of "plain" artifacts, whereas the higher classes used "luxurious" artifacts. Because the bench was socially represented as "plain" and this social representation was associated with "lower class" (and the "luxurious" mirror and hat hooks with the higher class of its owner), the bench (and the mirror and hat hooks) could be used to mark social class.

Even when it may seem that social change is due to the physical design of a technology, social representation processes often play an important role. Take, for example, the case of the atom bomb, which, Winner claims (1980), imposes a political constraint: it requires a strong, authoritarian security network because of its lethal properties, which means that there is a danger of theft or terrorist acts. But, in a sense, it is not the objective lethal properties of the bomb that impose this constraint, but rather a social representation of the bomb as having lethal properties and of posing risks when not guarded well. It is these perceptions of lethality and risk, and not any objective features of the artifact itself, that are the immediate cause of certain actors organising an authoritarian security network about the bomb. These perceptions of lethality and risk reduce resistance from third parties to this authoritarian network by legitimising its existence.

The problem with realist perspectives is that they systematically underestimate the importance of the mediating role of social representations between the technology and its social context. Technologies rarely *force* behaviour, in the sense of physically moving one's arm or stopping one's feet. Also, they do not *tell* people which new configurations or practices they enable. Instead, the direct basis of many social changes accompanying the use of a technology seems to lie in social representations of what a technology is and what it does. Importantly, these representations do not passively mirror the "objective properties" of the technology. Instead, it has often been shown in technology studies that technologies have "interpretive flexibility" (Pinch and Bijker 1987), in that people can attribute very different functions, abilities and properties to them.

## Social constructivism

Whereas realists tend to play down the role of social representations in the constitution of technological agency, social constructivists place all the emphasis on these. It is claimed that social representations not only play a major role in the constitution of agency, they also fully determine it. Alleged technological agency is wholly the product of the way in which artifacts are socially represented (and hence used). The examples of the baby clothes, the Victorian bench and the atom bomb in the previous section demonstrate the plausibility of this position.

Social constructivists maintain that artifacts have *interpretive flexibility*: different interpretations, or social representations, can be assigned to them, and these different interpretations assign different properties to them, not just regarding their function, but also regarding their technical content. Different social groups will occasionally represent an artifact quite differently. At other times, however, processes of social negotiation lead to *closure*: one social representation tends to dominate, henceforth determining the way the artifact is interpreted and consequently the human practices that evolve around it (Pinch and Bijker 1987). This whole process is sometimes described by a textual metaphor: artifacts are *texts* that allow for different readings of them (Woolgar 1991[a]). When closure is reached, however, one dominant reading of the text prevails, and alternative readings of them may become difficult. In a social constructivist conception of affordances and constraint, then, these are not constituted by inherent design features of the artifacts themselves, but rather by dominant social representations or "readings" of them. The design features of artifacts that seem to be responsible for constraint are actually social constructions.

Perhaps the most fully developed social constructivist theory of the agency of artifacts has been developed by Bryan Pfaffenberger (1992). Pfaffenberger is specifically concerned with political agency. He argues that the political agency of artifacts derives from *affordances*: perceived properties of artifacts that suggest how they should be used, or, more broadly, how they should be responded to. For instance, it is a perceived affordance of a cup that it can be used to drink water, but in certain settings it may also be a perceived affordance of a cup that it can be used to emphasise one's taste in choosing decor, or to hold model airplane parts. Affordances are not objective design features of artifacts but rather social constructions, or social representations, as they depend on a selective and constructive process of "reading" certain uses or meanings into artifacts.

For a particular way of "reading" an artifact (i.e., a particular affordance) to become dominant, it must be *discursively regulated*. That is, the affordance must be legitimated by a sufficiently persuasive discourse. The most persuasive discourses are symbolical discourses of myth, ritual and classification, rather than the verbal discourses of proposition and argument. So, for example, the affordance of Victorian hallway benches to express class distinction and humiliate the lower classes depended on a symbolic discourse that legitimated this affordance. This symbolic discourse derived from the Victorian myth of hygiene: the plain bench was presented as an artifact that had to be used by the servant class not because it would humiliate them, but because they had been on "public conveyances" and would therefore soil upholstery with the filth of the streets.

Pfaffenberger adds that discursive regulation in itself is usually insufficient to endow artifacts with political affordances. Discursive regulation must be accompanied by *secular ritual*, standardised practices that follow relatively well-defined scenarios involving various acts and objects that help regulate social behaviour. It is through secular ritual that the political affordances of an artifact come to life. For example, the politics of the Victorian hallway bench were brought to life through ritualisation of the hallway space. This space was the site of profound decorum standards, which called for members of the master's class to be admitted into the interior of the house straightaway, while members of the servant class were seated on the bench, thereby signifying their inferiority. To sum up, according to Pfaffenberger, affordances and constraints derive from perceived affordances of artifacts, which are social representations that are legitimated by symbolic discourses and that are brought to life through secular rituals.

If affordances and constraints derive from social representations rather than from physical design features, can constraints still be legitimately attributed to artifacts, or would it be more proper to say that artifacts do not impose constraints, but that social representations external to the artifacts do? This depends on how one defines "artifact". When "artifact" is taken to mean a physical object on which particular social representations are projected, then it should be clear that artifacts do not impose constraints. Hence, Pfaffenberger's answer to the question "Do artifacts have politics?" is that, in and of themselves, they do not (1992, 294). However, the term "artifact" is often reinterpreted within social constructivism as not denoting independently existing physical objects, but as denoting particular social representations of artifacts. After all, social constructivists often deny that there is any objective structure underlying social representations and claim instead that reality is made up of social representations: reality is a social construction. If artifacts are defined as social constructions, then it appears that artifacts are able to act.

Against social constructivism, it may be argued that it places *too much* weight on social processes and wrongly neglects the role of the physical design of artifacts. For there appear to be at least *some* affordances and constraints that derive at least partially from physical design properties. Indeed, artifacts sometimes seem to act in such a way that social representation does not appear to play an important role. Take, for example, the Long Island bridges that prevent buses from New York going under them to Long Island. This constraint (the exclusion of buses, not the exclusion of blacks) seems to derive from the physical design features of the artifact in question. Regardless of how these bridges are interpreted by bus drivers and others, they make it impossible for buses from New York to go to Long Island, as buses cannot pass under them. Let us call constraints of this sort that seem to work by physical means alone *physical constraints.*

We may distinguish *strong* physical constraints, which physically require or prevent certain actions, events or situations, from *weak* physical constraints, which merely promote, discourage, or hamper. Weak physical constraints are constraints that exert some amount of physical force, but can be countered, whereas strong physical constraints hold as a matter of physical law. For example, the prevention of buses going to Long Island as sketched above seems to be a strong negative constraint, as a certain event is made physically impossible. The encouragement to hotel guests to leave heavy hotel keys at the front desk by attaching weights to them is a weak positive constraint, as a certain event is made more likely to occur through physical force.

There are several types of constraints that seem to qualify as strong physical constraints:

1 F*orcing functions*

Forcing functions (Norman 1988, 132-38, 204-6) are physical constraints that require users to perform certain acts that not directly related to the purpose to which they want to use the artifact. An example is the forcing function imposed by the special interlock, required for a short period in history to be installed in each new car in the United States. Because of this interlock, the car would not start if the driver's and passengers' seatbelts were not fastened. So drivers had to fasten both seatbelts to be able to use the car.

Forcing functions are generally intentionally designed and are usually, though not invariably, included in the interest of safety. Norman distinguishes three types of forcing functions that are used in safety engineering: interlocks, lockins, and lockouts. *Interlocks* force operations to take place in proper sequence. For example, the pin on a fire extinguisher or the safety of a rifle requires certain functional acts to be performed before these devices can be used. Automated cash dispensers nowadays require users to remove their ATM card before money is issued. This order is engineered in order to help users not to forget their card. When people open the door of a microwave oven, an interlock automatically disconnects the power the instant the door is opened.

*Lockins* keep an operation active by preventing someone from prematurely stopping it. This seems to apply mainly to mechanical and electrical devices. For example, most computers nowadays have a "soft" on-off switch. When users turn off the computer, the power is not disconnected, but the computer first sends signals to programs to quit, checks that all files have been saved, and only then turns off the power. A *lockout* prevents persons from entering a place that is dangerous or otherwise off-limits, or prevents an unwanted event from occurring, by making sure that people only enter the place or use the device for the right reasons. For example, in public buildings, a bar is sometimes installed at the top of the stairs from the ground floor to the basement. This bar will help to prevent people from fleeing down the stairs into the basement when there is a fire in the building and they panic.

*2 User- and use-excluding physical constraints*
User-excluding physical constraints are physical constraints that exclude certain users from making proper use of an artifact. Use-excluding physical constraints are physical limitations on the use of an artifact. I shall now discuss them one by one. Artifacts impose a user-excluding physical constraints when they strongly require users to have certain physical attributes or be in possession of certain physical competencies, whether these derive from their own body or from artifacts used by them, like keys, cars, or hammers. For example, doorways will prevent creatures whose waist size is greater than the size of the doorway from entering. Fifty-pound bags of cement can only be lifted by construction workers who have the requisite physical strength. Computers can only be used by individuals who are not congenitally blind, or who have equipment that can transpose computer readouts to Braille or synthesized speech.

*3 Other strong physical constraints on actors*
Next to forcing functions and user- and use-excluding physical constraints, there are all kinds of other physical constraints that may affect actors. Users of artifacts may experience all kinds of constraints that do not directly affect their ability to use the artifact in particular ways but that nevertheless constrain their behaviour. For example, the use of a car requires the user to sit down and use his or her arms and legs. While driving, it is physically impossible to stand up or turn around to face backwards. ATMs require the user to obey a time limit, or else the transaction is canceled. Making use of a room with no windows implies not being able to see what is going on outside. The use of electrical appliances that are not accessible for repair or battery replacement implies that when the artifact breaks down, the user is physically prevented from making it work again. A car with two separate compartments physically prevents the driver from talking to, or touching, passengers in the back. Physical constraints may also be imposed on non-users. For example, the use of noisy machinery in construction makes it impossible for bystanders to have a normal conversation. A building may physically prevent pedestrians from seeing what is behind it.

Social constructivists have argued against the existence of physical constraints by claiming that what appear to be instances of physical constraints are actually social constructions, particular "readings" of artifacts that seem to refer to objective, physical conditions because they have become obdurate through closure. There are two variants of this argument. In the first, physical constraints are above all social constructions of the *users* of artifacts. Users are predisposed to "read" an artifact in a way that constrains them. They could, however, learn to "read" the artifact differently, after which the apparent physical constraint disappears. This argument is plausible for cases in which users seem to "misread" artifacts, or "read" them non-creatively. For example, an obese person may falsely believe that he/she cannot pass through a doorway whereas there are, in fact, ways of doing so. Against this social constructivist argument, it may be pointed out that there appear to be cases in which no change in "reading" habits seems to be able to remove the constraint. For example, it seems that no matter how bus drivers represent the Long Island overpasses, they will still not be able to drive under them with their bus.

A second version of the argument is that apparent physical constraints are really the social constructions of the *analyst.* Social constructivists may grant that there are physical constraints that, like Kant's things-in-themselves, impinge on the world, but may deny that these physical constraints are objectively verifiable by anyone, including the analyst. We only have reliable access to social representations, not to any reality behind them, and hence any pretenses of an analyst to have reliable knowledge of physical properties and physical constraints are misguided. The analyst who tries to divide up reality into objective physical features and socially constructed features is trying to make distinctions that cannot reliably be made (cf. Woolgar 1991[a]; Grint and Woolgar 1992, 1995).

For example, an analyst may observe that 20th-century kitchens only offered room for one worker and therefore did not support the sharing of kitchen duties (Wajcman 1991, 114). However, the belief of the analyst that these kitchens only offered room for one worker may be based on her unimaginative "reading" of these kitchens. Perhaps she sets very high criteria for what kinds of actions count as an acceptable use of a kitchen, and does not consider how users may come up with creative solutions to divide up the available space in a way that makes it possible for two people to use it simultaneously. Similarly, an analyst of the Victorian hallway bench may wrongly identify certain relevant properties as objective whereas these are really dependent on his biased social representations. For example, the analyst may identify the bench as "plain", whereas its plainness is really a cultural construct. Or he may observe that members of the lower classes would often bring in filth that would stain benches with upholstery, not noticing that "filth" and "staining" do not denote objective phenomena, but imply particular value judgements.

One can object to this argument that even if users or analysts are never in possession of fully "objective" representations of artifacts, there are enough instances of physical properties or physical constraints that are so uncontroversial that it seems silly not to make recourse to them in accounting for affordances and constraints. For example, it seems to be a plain fact that 10-ft. buses do not fit under 9-ft. bridges. And whereas two people may perhaps use a small kitchen simultaneously, the same is clearly impossible for 20 people. Hence, some constraints imposed by artifacts appear to be self-evident, and incontrovertible.

Against this objection, Woolgar (1991[a], 32) has claimed that "the whole point of interpretive flexibility is that apparent 'self-evidence' and 'incontrovertibility' are social accomplishments that are subject to change. Our recourse to self-evidence merely buys into one current definition. And it would be a pity to limit the scope of the theory to technologies whose impact currently happens to be controversial". Woolgar's point is that buying into self-evident or uncontroversial "truths" about technical artifacts biases the analysis because these "truths" are actually contingent social representations. Also, it may make analyses shallow by excluding the possibility of more profound critiques of affordances and constraints that question accepted truths. For example, an analyst in Victorian times, and even a present-day observer, might have missed the fact that some properties of Victorian hallway benches, such as their "plainness" and their "better resistance to filth" are, in fact, contestable social constructions that are part of the discourse that was used to humiliate the lower classes: it draws from a particular myth on aesthetics and hygiene.

I believe that Woolgar is right that our perceptions of "objective" physical features of artifacts always involve an amount of social construction, and that serious attention should be paid to uncover particular biases in these perceptions. However, I also believe that there are limits to such reflexive activity, and that it sometimes pays too little to keep questioning the "objectivity" of certain putative physical properties or constraints. For example, it is unclear what will be the gain from deconstructions of the claim that 10-ft. buses do not fit under 9-ft. bridges. In contrast, much can occasionally be gained if the analyst is allowed to make reference to this "fact" in an analysis. Therefore, I believe that analysts should be allowed to appeal, with caution, to physical properties and constraints in their analyses. Social constructivism cannot do this and hence cannot give a complete account of technologically induced social change.

## Hybrid constructivism

The term "hybrid constructivism" can be taken to refer to any position that adopts the *principle of generalised symmetry*. This is a methodological principle according to which any relevant elements referred to in an analysis (whether "social", "natural", or "technical") should be assigned a similar explanatory role and should be analysed by the same (i.e., symmetrical) type of vocabulary (Callon 1987; Latour 1987; Callon and Latour 1992; Callon, Law and Rip 1986). Hybrid constructivists (many of whom define their work as taking place within *actor-network theory*) analyse phenomena, such as the workings of an artifact, as the result of the activity of a heterogeneous network of entities that work to co-construct the phenomenon. These entities are not treated differently in the analysis because they are labelled as "social" (or "human") or "technical" or "natural" ("nonhuman"). All are *actants* (things that act) that have similar (i.e., symmetrical) explanatory roles.[3]

Social constructivism is criticised by hybrid constructivists for assigning a special role in analysis to social elements, such as social groups and the social representations they employ, whereas "natural" or "technical" elements, such as natural forces and technical devices, are prohibited from being explanatory factors in explanations. Hybrid constructivists also allow for technical devices and natural forces to be actants in networks through which particular phenomena are constituted. By an analysis of actant networks, any phenomenon can be shown to be a *post hoc* construction, the consequence of the stabilisation of a whole network of human and nonhuman actors. This does not mean, however, that these phenomena are *socially* constructed, because the phenomenon is not only the result of social factors. It is the result of heterogeneous elements, all of which are accounted for by the same, symmetrical vocabulary, and none of which are explicitly identified as "social", "technical", etc.

By thus rejecting the traditional distinction between nature and society (and hence between the naturally given and the socially constructed), hybrid constructivists reject a distinction maintained by both realists and social constructivists. Realists maintain that even though there are social entities, and even though some facts or objects may be socially constructed (e.g., money, marriages, and other social objects; cf. Searle 1995), there are also purely physical and technical processes, facts, and objects that may sometimes, as with technical artifacts, have been constructed by humans and may have involved human choices in their design, but have physical properties that are ontologically independent of social interpretation or negotiation. Social constructivists maintain the distinction as well, but move in a different direction than realists do: instead of saying that socially constructed objects have a physical basis, they argue that the natural and the technical are constructed out of the social.

Its proponents hold hybrid constructivism to be plausible because they believe that realists and social constructivists, who maintain an asymmetrical vocabulary, fail in their attempts to explain the various scientific and technical phenomena. Realists and social constructivists maintain distinctions that stand in the way of good methodology, which is methodology in which sound generalisations can be made to account for the complex interactions of people and things. Both cannot adequately account for moves "from action to behaviour, from meaning to force, from culture to nature" (Callon and Latour 1992, 361). The problem with realist analysis of technology, according to hybrid constructivists, is that it cannot shake off an unwarranted technological determinism, according to which technology by itself affects change in the world. The problem with social constructivist analyses is that nonhuman objects are left powerless; only humans act, even though technical and natural objects appear to play the role of intermediaries in all kinds of processes. As Callon and Latour conclude: "The choice is simple: either we alternate between two absurdities, or we redistribute actantional roles" (356).

The symmetrical model for the analysis of technology has perhaps been developed most fully by Bruno Latour (1988[a], 1988[d], 1992, 1995[a]; Akrich and Latour 1992). In Latour's vocabulary, no principled distinction is made between humans and nonhumans; all are actors, or *actants*, that are able to act, mediate, and influence. Actants are assigned *competencies*, that is, powers to act. The competencies of actants in a setting cannot be determined beforehand, but can only be attributed to them as the result of analysis of the whole setting in which they operate. The same is true of their *performances*: the concrete actions they perform in a particular setting. And, it may be added, the same is true of any generalisations, or *laws*, stated over the performances of actants. Notice that, in this vocabulary, the whole distinction between physical objects and human actors, physical capacities and behavioural dispositions, physical processes and human actions, and physical laws and social norms or habits disappears: there is only an interplay of actants and their performances, which are all described in the same terms.

Actants may form *associations*, or links. This happens when two or more actants start interacting with each other on a structural basis. For example, an association is formed between a door and a door closer when the door closer systematically closes the door after it is left open. A similar association would arise if the door closer were to be replaced by a human butler who was trained to close the door at all times. Another association would be the link between a traffic policeman directing traffic and a road user obeying these directions. A similar link may exist between a road user and a traffic light. Again, it does not matter in the description whether the links are between human or nonhuman actants. When multiple actants form links with each other, *networks* of actants emerge. The *stabilisation* of a network is the process by which associations in a network become stable, or solidify.

Now, Latour maintains that any fact about the competencies and performances of a particular technical artifact (or, for that matter, a scientific phenomenon, or any other entity) is the product of a network of actants that jointly work to "produce" this fact. Take, for example, the fact that a traffic light is able to direct traffic. This is not an intrinsic technical capacity of a traffic light, but is rather the result of a stabilised network of actants. These actants include the traffic light itself, but also the road users, who are disciplined to respond to changes in the traffic light in particular ways, and it includes elements of the infrastructure that support the working of the traffic light (e.g., electricity cables) and elements of the road system used by the road user (e.g., the vehicle, the asphalt under the vehicle). It is the total stabilised network of actants that ensures that the traffic light has the competence to direct traffic.

Latour developed a whole vocabulary for the analysis of such actant networks. I shall now discuss some of its key terms, beyond the ones already mentioned. *Delegation*, or *translation*, is a process by which certain actions performed by one or more actants are transferred to other actants that perform them more effectively or efficiently.[4] For example, in a hotel in which guests constantly leave the front door open, it can be decided that closing the door should be delegated from the guests (who do not form a stable door-closing link with the door) to a groom, or a door closer. When delegation indeed results in more durable associations, then it may be called an *inscription* (or *encoding*). Because machines often create more durable associations than humans do, inscription often involves the delegation of human actions to a machine. However, the embodiment in cultural tradition of the owner manual of a car is also an inscription, as the instructions in the manual will be more reliable when they are part of everyday knowledge than when they are written down in a leaflet that must be consulted continually.

*Prescriptions* (or *affordances*) are what a scene or setting, or a specific actant in a scene, forbids or permits particular actants to do. The term is most often used by Latour to describe presuppositions that technical artifacts (as embedded in, and defined by, a network of actants) have about the behaviours and attributes of their users. As Latour remarks, prescription "is very much like 'role expectation' in sociology, except that it may be inscribed or encoded in a machine" (1988[d], 306).[5] Prescriptions need not be obeyed: the user may not be properly attuned to the prescriptions, and may refuse to follow up on them. For example, a traffic light expects that its users will perceive it from the street and not from one side. A hotel key with a heavy ball attached to it expects guests to return it to the front desk, but guests need not obey this prescription. *Scripts* are the scenarios, or roles, played by human or nonhuman actors in a setting when they obey the various prescriptions inscribed in a scene, or inscribed in a particular actant in a scene. When defined relative to an artifact, a script is the framework of action, in conjunction with the actors and the space in which they are supposed to act, which is presupposed by the artifact and any other actants that help to define its prescriptions (e.g., notices, manuals).

Actants (and scenes, and networks of actors) may also be assigned *programs of actions,* that is, goals that they "try" to reach and that are made the point of departure of an analysis. The associations of actants in a setting, and changes in these associations (and the competencies of actants, and hence their prescriptions) over the course of time can then be described in terms of their effect on this program of actions. For example, the scene, mentioned earlier, of the hotel door that should be kept closed may be analysed from the "keep-the-door-shut" program of actions. This may be a goal of the hotel manager, and it may become a goal of properly disciplined guests, as well as grooms and other delegates such as notices and door closers. *Antiprograms* are programs of action of actants that are in conflict with the program of actions chosen as the point of departure of the analysis. For example, hotel guests may be too rushed to close the door behind them, and some may even leave the door open intentionally for fresh air. A well-designed artifact (such as a good door closer) carefully anticipates various antiprograms to the degree that is able to let its own program of actions prevail over them. A program of actions is successful when the prescriptions of an artifact and its allied actants yield a script that conforms to this program of actions and is resistant to the antiprograms of other actants. To be successful in this way, artifacts must participate in a system of alliances with other actants that help issue a set of prescriptions.

So what is agency within this theoretical framework? Agency can be reduced to prescriptions issued by artifacts. Strong prescriptions are ones that the actant(s) to which the prescription is issued is/are somehow disposed to obey. Their competencies are such that they respond to the prescription by obeying it. It does not matter if the constraint is physical or symbolic (social, representational). For example, red traffic lights issue a strong stopping constraint to most drivers, because most drivers are strongly disposed to stop at a red light. Moreover, it does not matter whether the obedience of a prescription is willing or not; the important element is whether the prescription is sufficiently powerful. For example, a car that is wired to start only when the driver wears a seat belt may force its driver to obey the prescription "wear a seat belt (or you cannot drive the car)". Only a driver who has the competence to disable the wiring will be able to evade this prescription.

Strong prescriptions may *exclude* human actants (especially users) when they are unable to play the roles required of them, even if they desire to, because they lack the required competencies. For instance, an ATM may require its users to be literate, thus excluding illiterate prospective users. Alternatively, strong affordances and constraints may *frustrate* human actants because they are only able to play the required role by adapting (i.e., by developing the required competencies). For example, a door that is 6 ft. high requires someone who is 7 ft. high to stoop ("become a smaller person") when entering.

A *weak* prescription is one that may fail because the actants to which it is issued may not have the required disposition. For example, a car that flashes a warning when the driver wears no seat belt may not succeed in compelling the driver to wear a seat belt, because the driver can choose to ignore the warning light. Even physical force may only serve as a weak constraint when an actant subjected to it has the competence to resist it and carries an antiprogram against this force. For example, the Long Island bridges discussed earlier will not stop buses when the buses have the physical strength (competence) to ram through them and the bus drivers are disposed not to stop for the bridges.[6]

Notice that although Latour sometimes attributes prescriptions to particular artifacts, he does not hold that these prescriptions are the result of competencies intrinsic to the artifact and that they reveal themselves in appropriate settings. This would make his approach resemble a contextual realist one. Latour maintains that competencies cannot be discovered by studying artifacts in isolation. They are inherently relational: they are realised as the product of the embedding of an artifact in a network of associated actants. When this kind of network stabilises, competencies emerge as *black boxes*, that is, as apparently transparent properties of actants that obscure the fact that they depend on the network of alliances of which the actant is a part. Artifacts gain their identity only within such networks, and hence technological innovation is not just the isolated development of a new artifact, but the modification and development of a network of associations of which this artifact is to be a part.

The apparent advantages of a hybrid constructivist approach over a realist or a social constructivist one are twofold. First, hybrid constructivism does not need to determine whether properties of artifacts that give rise to social changes are either objective physical features or social constructions. It does not need to say, for example, whether the properties of Victorian hallway benches that help demarcate class (e.g., their hardness or their plainness) are either objective properties or social constructions. Is its hardness objective or socially constructed? What about plainness? In a hybrid constructivist framework, it does not matter because both physical properties (if any exist) and social representations, or any hybrid mixture of them, are treated identically: as a competence of an actant that may or may not help it to build associations with other actants.

Second, by transcending the distinction between the social and natural/technical (or between signs and things), hybrid constructivism is able to state generalisations about affordances and constraints that could not be stated if this distinction were to be maintained, because then the required vocabulary would not be available to make such generalisations. In a hybrid framework, it is easier to see how a physical artifact translates human behaviour into a more durable form, for example, or how a human groom and a door closer are instances of the same process of delegation. As a flipside to this, analyses are also less cluttered by distinctions (between signs and physical objects, social actions and physical behaviour, etc.) that are irrelevant to the analysis.

I agree that these are both real advantages of hybrid constructivism. However, I believe that they are not decisive in its favour. Although the vocabulary of hybrid constructivism enables generalisations on the affordances and constraints of artifacts that are not possible in a vocabulary that maintains the natural-social distinction, it pays the price of forfeiting detail. Because it cannot refer to things as social or natural or technical, because it cannot use these traditional categories, it cannot discern any meaningful distinctions between physical and semiotic force, or between physical and social processes, and any relevant differences between the two cannot be made to play a role in the analysis. For example, the strategies by which human actors may try to resist symbolic force and physical force are surely different. Resistance to physical force may result in the disabling or modification of artifacts, whereas resistance to the force of symbols may result in the production of alternative symbols (cf. Pfaffenberger 1992). Similarly, it seems to be relevant whether prescriptions target human or nonhuman actants. Human actants have a richer behavioural repertoire by which they can respond to prescriptions, and humans may have various intentions, beliefs and motivations that may be relevant in the analysis. In a hybrid vocabulary, these differences between humans and nonhumans are obscured in the interest of symmetrical treatment.

Since the mid-1990s, actor-network theorists have moved beyond some of the basic tenets of ANT as it was developed up until the early 1990s (Law and Hassard 1999; Lee and Brown 1994). Specifically, many now do not want to claim that ANT contains a coherent set of principles, but emphasise the diversity of approaches in ANT, and the diversity of ways in which links between actants in networks can be created by the analyst, and the need to tell multiple possible inconsistent narratives about technologies rather than a single consistent narrative. Parallel to this, there has been greater emphasis on multiplicity and difference, on the disorder of networks, and the heterogeneous ways in which actants take on actantional roles and are multiply realised in different, partially overlapping networks. These recent approaches, however, still make use of limited hybrid vocabularies that fail to recognise fine-grained differences that appear relevant in the much richer traditional vocabulary in which differences between the social, the natural and the technical are acknowledged.

## Differentiated constructivism

The defense of hybrid constructivism rests in part on the supposition that it is the only alternative to realism and social constructivism. I now want to argue that a fourth position is possible, *differentiated constructivism*, which avoids some of the weaknesses of realism and social constructivism. Differentiated constructivism is the standpoint that the agency of artifacts results partly from the material design structure of artifacts (*pace* realism) and partly from social processes (*pace* social constructivism). It is believed that, although it is often difficult to separate these two contributing factors (*pace* hybrid constructivism), this kind of separation usually can and should be included in the analysis. Just like hybrid constructivism, differentiated constructivism neither privileges the natural or technical nor the social or symbolical. Yet, it holds that *some* affordances and constraints correlated with artifacts are physical in nature, whereas *others* result from social representation. It also holds that affordances and constraints may be *in part* physical and *in part* social, and that it is possible to distinguish between these respective parts in analyses. Hence, *some* constraints are physical, *others* are socially constructed, and *yet others* are a combination of physical and social factors. Differentiated constructivism is hence a position on the agency of artifacts that maintains the distinction between the physical/technical and the social/symbolical (and hence rejects the generalised principle of symmetry), but also rejects exclusively realist and social constructivist accounts of affordances and constraints.

To illustrate this position, let us reconsider the (social constructivist) analysis of demarcation of social status by the Victorian hallway bench (section 2). In a differentiated constructivist analysis, it might be analysed that the bench has certain objective properties. For example, it is hard and does not have many elegant carvings. These objective properties constrain certain perceptions (social representations) of the bench, for example, that it is plain. Plainness was a social construction that was associated with the lower classes in Victorian times. Because only people from the lower classes were told to use these benches, they therefore functioned as a means to mark social class. The difference between this analysis and the social constructivist analysis is that it goes outside social representations in the analysis of this constraint to appeal to "objective" physical properties of the artifact. These play a role, along with social representations, in the constitution of affordances and constraints.

Similarly, a differentiated constructivist analysis of political constraints imposed by the atom bomb would go along with the social constructivist supposition that the organisation of an authoritarian security network around the bomb is motivated by social representations that attribute lethal properties to it. It would then go on to analyse these social representations to be dependent on the presence of actual lethal properties in the bomb.[7] Differentiated constructivists may grant that, for some affordances and constraints, the physical properties of the artifact play a wholly arbitrary role. Thus, the fact that pink baby clothes for girls promotes gender stereotypes may be rightly analysed as resting on a cultural convention or symbolism that arbitrarily connects perceptions of pink with stereotypical feminine traits. Still, then, it may be emphasised that the perceived pinkness of the clothes is not an arbitrary social construction, but is based on actual physical properties of the clothes.

The above examples illustrate a variety of differentiated constructivism that is closer to social constructivism than to realism in that it is still ultimately social representations that generate affordances and constraint, even if these social representations are themselves constrained by actual physical properties of artifacts. Hence, these physical properties only issue *indirect* constraints. A variety of differentiated constructivism that is closer to realism holds that physical properties of artifacts sometimes impose more *direct* constraints, that is, constraints unmediated by social representations. Often, these are constraints that result from the fact that the artifact exerts *physical force*: it makes certain states of affairs physically improbable or even impossible, or makes them physically probable or even necessary. For example, a locked door imposes the constraint that those who open it have to have a fitting key (or have another means to take away the physical resistance of the door that prevents them from entering). This constraint is in place because the door will physically resist anyone from entering who does not have a fitting key. How the door is represented by that person appears to be irrelevant to this fact.

Or consider the modern Western sofa, which has separate seat cushions that define distinct personal spaces and hence work to respect and perpetuate modern Western culture's emphasis on individuality and privacy. In part, this perpetuation of privacy derives from perceptions of the divisions between the cushions, and the learned convention that it is impolite to cross these when sitting next to someone with whom one is not intimate. However, these divisions do not just generate particular social representations, they also constitute a gap that makes it less comfortable to cross it, and hence in this way exerts some amount of physical force that stimulates people to remain within the confines of one seat cushion. Similarly, a heavy hotel key exerts a weak physical force on guests, stimulating them to return it to the front desk when leaving. Sometimes, this force may just serve a symbolic function, by reminding them to return the key. In other cases, the perceived discomfort may cause guests to return the key that they would otherwise have preferred to take with them.[8]

Physical properties of artifacts do not always work to make things happen or prevent them from happening by exercising physical force. They may also make it possible for new things to happen by physically creating *new opportunities.* In an environment in which human actors actively seize this new opportunity, technology may be interpreted as imposing a constraint. For example, the installation of running water and washing machines in houses on Ibiza, Spain, made it possible for people to do their washing and laundering inside. Because many inhabitants preferred doing this to using the public fountain and washbasin, these fountains and washbasins were consequently abandoned. As a result, the social ties between Ibizans weakened. This social constraint is not physically necessitated by the new technology, but is afforded by it, and in the right environment, such an affordance turns into a constraint.

What, finally, makes differentiated constructivism a constructivist position, rather than a variety of realism? This, I submit, depends on how these two positions are defined. Nothing important hinges on it. I earlier defined the realist position as holding that affordances and constraints have their basis in the material design structure of artifacts, and the constructivist position as holding that affordances and constraints are partially or wholly the product of processes external to the artifact. I also claimed that realists normally play down the role of social representation in human-artifact interactions and that human agents normally respond to artifacts on the basis of their objective physical features. Now, differentiated constructivism retains the realist premise that artifacts have real physical properties that can be analysed by the analyst independently of third-person social representations of these properties. For some, it would suffice to call this position "realism" instead. However, I put more weight on the fact that differentiated constructivism, unlike mainstream realism, assigns a major role to social representation processes external to the artifact, and holds that human agents normally respond to such social representations in their interaction with artifacts, rather than (just) to their objective physical qualities.

I want to claim, finally, that it may not be necessary to *choose* between a hybrid or a differentiated constructivist account. Both may have a role in analysis. With a hybrid vocabulary, it is possible to state broader generalisations in the analysis of affordances and constraints. The analysis may then be extended and deepened by employing the vocabulary of differentiated constructivism, which retains a number of distinctions that disappear within a hybrid vocabulary. This latter analysis may reveal more specific mechanisms of translation, delegation, and prescription that are difficult to uncover within the generic vocabulary of hybrid constructivism. Indeed, in his analyses, Latour makes frequent use of asymmetrical terms in addition to his hybrid terminology, by describing actants as "human" or "nonhuman", by attributing intentions and desires to humans, and by calling things and events "technical" or "social". These descriptions often seem to deepen, rather than undermine, his analyses.

## Conclusion

Hybrid constructivists rightly point out that agency is not produced by artifacts themselves, nor by social processes external to artifacts. It is the product of actor-networks in which the physical behaviour of artifacts and the social behaviour of humans blend together into a knot that is often difficult to untie. Both humans and nonhumans are agents ("actants") in that they have a causal or structural role within the network. Yet, I have argued, the vocabulary of hybrid constructivism is too general to untie the knot of actor-networks completely. A differentiated constructivist approach can more specifically point to the relative contributions of artifacts, social representations, and other structures and processes.

## Notes

1 The factual accuracy of the case has been contested by Woolgar and Cooper (1999), who claim that the bridges in question did not in fact work to block bus access to Long Island. I will use the case here only as a hypothetical example of

how different approaches may treat the political role of an artifact like a bridge, assuming, for the sake of discussion, that they actually block bus access.

2 Indeed, the setting has changed since the 1960s. One change since then is the emergence of the camper van. The bridges now also discriminate against owners of camper vans, who cannot pass under them.

3 Well-known work within a hybrid constructivist framework has been performed by Latour, Akrich, Callon, and Law (all adherents of actor-network theory). Bijker has also converted to this position (Bijker 1992). Bijker, however, still calls his position "social constructivism", unlike Latour, who defines social constructivism according to my above definition, and holds the principle of generalised symmetry to be incompatible with social constructivism. Cf. Callon and Latour (1992).

4 Latour and Akrich sometimes appear to use the term "translation" more broadly for any transfer of action from one group of actants to another, whether or not these latter actants perform the action more efficiently or effectively.

5 Prescriptions are similar to what Pfaffenberger (1992) calls affordances. Notice that "affordance" is also used as a synonym of "prescription" by Latour.

6 The strength of an artifact constraint, or prescription, is hence in Latour's theory relative to the competencies and attunements of actants that it is aimed at. Artifact constraints may, however, also be called weak or strong in a more absolute sense, that is, relative to "normal" or "average" actants. The Long Island bridges may then be said to issue a strong constraint, in that average buses will not be able to resist them.

7 Notice that such analyses would then not only break with the generalised principle of symmetry of hybrid constructivism, which holds that humans and nonhumans must be treated in the same way, but also with the social constructivist principle of symmetry, according to which no assumptions are made in analyses about the truth of scientific claims or about the actual properties of technologies. It hence assigns to the analyst the competence to know the difference between reality and representation (or between "good" and "bad" representations). As will be argued later on, the analyst will not always be in a position to claim this competence, but may sometimes legitimately claim it.

8 Notice that, as artifacts become part of everyday life, constraints issued by them that result from their capacity to exercise physical force may no longer be issued by their actual exercise of physical force, but by the perception of human agents that the artifact has this capacity. Human agents will then often act in accordance to the constraint so that they are not subjected to physical force. So most people will not try to walk through doors that they know to be locked and for which they do not have a key, and if they believe their key to be heavy, hotel guests may decide to return it to the front desk before lifting it.

# Diversity and Distributed Agency in the Design and Use of Medical Video-Communication Technologies

*Nelly Oudshoorn, Margo Brouns, and Ellen van Oost*

## Introduction

Imagine a scene in a hospital. In the intensive care unit, a nurse is taking care of a tiny, premature baby that moves restlessly in the incubator. When the nurse has reassured herself that everything is okay, she installs the camera that watches over the baby in the incubator. The signals from the camera are sent to the central control unit in the hospital and to yet another location, thirty miles from the hospital where, connected by means of telephone cables, the parents of the child try to operate the video-communication system they have received from the hospital. If they can manage, they will be able to see their baby without leaving their living room. A fourth location, not materially connected to the three previously mentioned locations but nevertheless important to this story, is the hospital management room. The manager in charge of the introduction of the Baby Watch, as this video apparatus is called, discusses the risks of legal claims against the hospital in the case of when something appears to go wrong while the parents are recording their child's medical treatment via the Baby Watch. What all of these situations have in common is that they represent different contexts of use and users that are part of a heterogeneous network of actors – people as well as objects – that jointly constitute a new practice in the supervision of premature babies.

In this chapter, we aim to analyse the role of the diverse actors – both human and nonhuman – in the development of this new practice, this hybrid, heterogeneous network. In our analysis, the design and use of a new technology are intimately entwined. The notion of script is relevant to conceptualising the connection of design and use. Akrich (1992) introduced this concept to visualise the way in which innovators' representations of users shape technological development. In the design phase, actors construct many different images of users and objectify these representations in technological choices. The very act of identifying specific individuals or groups as users may facilitate or constrain the actual role that specific groups of users are allowed to play in shaping the development and use of technologies. The inscription of representations of users and use in artifacts results in technologies that contain a script: they attribute and delegate specific competencies, actions, and responsibilities to users and technological artifacts. As such, technological artifacts – nonhuman actors – are not neutral actors in the socio-technical configuration, or "hybrid collective" to use Latour's terminology. Like humans, nonhumans can act, have intentions (mediated), can delegate, distribute responsibilities, etc. This symmetrical analysis of humans and nonhumans is one of the most important merits of actor-network theory and has undoubtedly shed new light on the way technology configures practices (medical and other) (Pasveer and Akrich 1996; Lehoux et al. 1999).

Although the script approach, as developed by Akrich, is potentially adequate for our analysis, it tends to neglect the diversity of user groups involved as well as the heterogeneity within these groups. Whereas Akrich briefly mentions that there is usually a variety of different user representations at work in the design process, her semiotic approach does not provide any theoretical reflections or conceptual tools to acknowledge the heterogeneity within user groups and differences in agency between user spokespersons, nor does it specify explicitly how change might be accomplished.

This chapter seeks to explore how technologies may contribute to (a)symmetry in agency and control among users and user spokespersons, i.e., end users, intermediary users, and commissioners. A second and equally important aim is to understand the processes underlying the design of technologies for multiple users.

To do so, we adopt the concept of distributed agency. As actor-network theory suggests, agency is not an a priori given feature of an actor but is the outcome of interactions between the heterogeneous actors in the network. The notion of "distributed agency" emphasises that agency is not located in an individual actor, but is distributed among diverse (human as well as nonhuman) actors that jointly form a collective actor (Gomart and Hennion 1999). Technological artifacts not only distribute agency among people and things, they may also delegate agency to specific groups of users and not to others. We do not set ourselves the task of elaborating a theoretical conceptualisation of this type of agency that does not privilege humans above nonhumans, as classical sociology does. Latour has tried to redefine agency/action to include nonhumans in sociological theory (Latour 1996[a], 237) but failed, even in his own estimation (Latour 1996[b], 269).[1] Instead, we shall elaborate the concept of distributed agency empirically and, based on this exercise, discuss the benefits and problems of this concept. We consider distributed agency as a potentially interesting concept because it retains the valuable contribution of actor-network theory, that is, the symmetrical inclusion of nonhumans and humans in sociological analysis, whereas two points of criticism of actor-network theory are obviated: that actor-network theory ignores differences among actors and that it pays exclusive attention to experts, engineers, and producers (Clarke 1998, 267; Star 1991).

Our concern in writing this chapter is to understand how new technologies contribute to the equal/unequal distribution of agency over the diverse user groups. Social issues like equality and inequality and the implicit or explicit exclusion of vulnerable social groups in relation to new technologies are at the core of our research motivation. Our research builds on a feminist tradition in technology studies where attention to users is important. The feminist concern has been, and remains, the virtually exclusive attention paid to experts in actor-network theory ("the executive approach") which tends to preclude knowledge from the vantage point of non-standard positions, including women's voices. Feminist scholars argue that it is important to include the "silent" and "silenced" voices of less-powerful actors than experts and producers in technology studies (Star 1991; Clarke and Montini 1993, Clarke 1998; Saetnan et al. 2000).

This argument reflects a political and theoretical perspective. Politically, feminists argue for an engagement with those individuals and groups who are affected downstream by products of technological innovation (Casper and Clarke 1998). In a situation of multiple user groups, which is often the case in medical technologies, the end-users run the risk of being marginalised in the design process (Berg et al. 1999). A more detailed understanding of the role of users as actors, how they are represented, and how they are endowed with agency in the process of development and use of new technology may provide useful information for the empowerment of users or user spokespersons, such as patient groups and consumer groups, to envisage technologies that match their interests and increase their agency. Theoretically, feminists denounce the idea that science and technology in action begin or end with the actions of scientists and engineers. They emphasise the importance of acknowledging the heterogeneity of actors in networks of technological development and use (Rapp 1998, 48). The concept of distributed agency may well contribute to the development of this theoretical and political perspective.

In this chapter, we shall present our study of the design process of a video-communication system that enables parents of premature babies to visit, in a "virtual" sense, the neonatology ward of a hospital to watch their baby.[2] The design trajectory encompassed different artifacts. Each artifact was actually put into use, which enables us to describe and analyse the developmental process as an intimate entwining of design and use. In analysing the transformations in the heterogeneous network of actors involved in the design and use of the video-communication system, we first describe the ways in which the script of the technology organises and structures the network in terms of the distribution of control and agency among the different actors, human as well as nonhuman, with a particular interest in asymmetries between the different human actors. We continue by analysing the design processes underlying the development of this technology. What influence do the different user groups have on actual design choices? We conclude by discussing the extent to which the concept of distributed agency is the appropriate tool to account for equalities and inequalities among the heterogeneous actors in shaping technological development.

## The birth and development of Baby Watch

New technological products can have different origins. Whereas some products have been designed in reaction to specific demands or for the purpose of solving specific problems (technology pull), other products are developed because designers want to experiment with different technological possibilities to create new markets (technology push). Baby Watch is typically a product of the latter. For a long time, the Royal Dutch Telephone Company was a public company, and the only provider of telephone services in the Netherlands. This monopoly position was seriously challenged when the Dutch Government decided to give up its ownership and to create conditions for a competitive telecommunications market. As a privatised organisation, Royal Dutch Telephone had to re-orient itself to new clients and future markets. In this re-orientation, they considered video-communication as one of the promising markets. In the early 1990s, the R&D department of Royal Dutch Telephone developed an algorithm for compressing video images so that they could be transmitted via analogue lines. The firm developed a demonstration set using a laptop computer, and tried to generate experiments and orders for developing new products based on this technology.

The account manager of Royal Dutch Telephone, who served as the permanent intermediary between Royal Dutch Telephone and the Radboud Hospital in Nijmegen and was responsible for creating opportunities to introduce new communications products, presented the demonstration set during one of his regular visits to the hospital. Although the performance of the demonstration set was rather limited – only pictures the size of a postage stamp could be transmitted – the hospital's response was positive: "We were looking for this kind of communication".[3] The Radboud Hospital was interested in developing new services for its clients, a project allowing the hospital to present itself as a modern hospital using the latest technologies with the aim of increasing customer satisfaction. The neonatology ward promised to provide a suitable location to initiate the new services. In the neonatology ward, the medical and caring systems are primarily oriented towards newborn babies, vulnerable due to premature or early birth. The parents worry about the future of their child, the mothers are often weakened by childbirth. The babies end up staying in the academic hospital for quite a long time. The patients come from different places, not only from the immediate neighbourhood of Nijmegen, but even from Germany. The management of the hospital saw a new video-communication system, which enabled parents to have contact with their child from their home, as an adequate tool to create a new communication line between parents and their baby, and as a new service that could attract patients from wider regions.

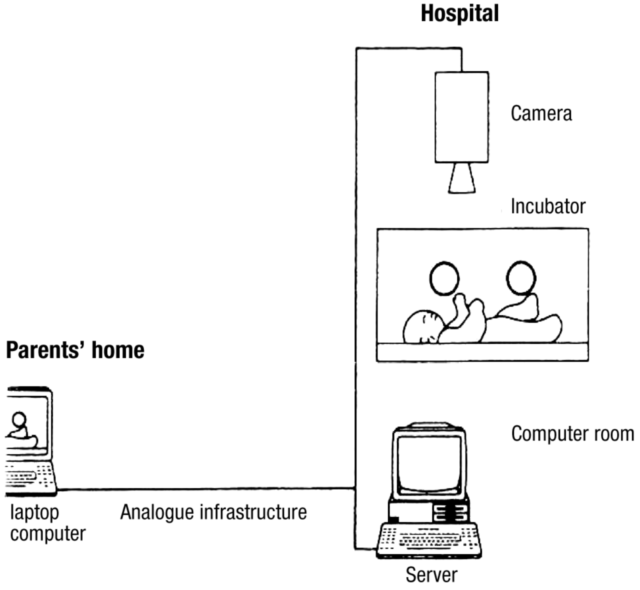
To Royal Dutch Telephone, the academic hospital was a promising experimental site for developing video-communication systems. Hospitals function in an extensive web of internal and external communication between different groups: medical staff, nurses, patients and their families, students, insurance companies, and governments. This makes the hospital a potential major customer for telecommunication services. The development of a video-communication system thus served the interests of both parties. In early 1994, the Radboud Hospital management and Royal Dutch Telephone, financially supported by two insurance companies, decided to develop a video-communication system for the neonatology ward, called Baby Watch.

The development of this new medical video-communication system resembles the career of Michael Prince: the artifact has lived through quite drastic changes, even to the extent that each product was given a different name. The first system envisaged, Baby Watch, was based on the same technology as the demonstration set, using a laptop, modem and telephone. Not only did the compression software need to be improved in order to produce images of sufficient quality, but a user interface aimed at the specific user group also had to be developed. At the end of 1995, the technical designers could present the first prototype of the Baby Watch system. During 1996 and 1997, this system was implemented and adapted to the specific circumstances at the hospital. In 1998, Baby Watch was replaced by a completely new system, VIATV Phone. This system, also developed by Royal Dutch Telephone, used the TV to show the images. It was, however, yet another application of this technology that became the proclaimed commercial video-communication product, "Magic TV", designed to be used in the children's oncology ward. In commercial terms, Magic TV is Royal Dutch Telephone's most successful product, since it is easier for hospitals to raise funds for young cancer patients.

Altogether, Royal Dutch Telephone developed two different technologies (respectively, a computer-based technology and a TV-based technology) and three different products: Baby Watch, the VIATV Phone, and Magic TV. The following section analyses the scripts of these three different products.

### Delegation and distribution of agency and control by the video-communication systems

The initial Baby Watch system consisted of a camera attached to the incubator and connected to a server in a room nearby. The parents had a laptop with a specially developed Baby Watch interface and a modem to connect the laptop to the telephone line at home. The telephone line was used for communication between the parents and the nurses and for sending the pictures from the camera to the laptop. The nurses controlled the pictures on a monitor before opening the line. The design is as follows:



Once this first prototype was set up, most of the responsibilities and control were delegated to the nurses. The parents had to telephone the nurses and ask them to activate the camera. As a result, the agency of the parents was restricted. First of all, they were dependent on the nurses to make the connection. Then the nurse initiated the system and controlled the monitor. If the parents switched on the PC at home, they were then able to watch their child on a laptop screen. A second restriction to the parents' agency was that they never obtained a connection when the baby was being medically treated. Last, but not least, they could only receive images and no sounds. The Baby Watch thus incorporated a clear script that delegated responsibilities, agency, and control to specific users and created dependencies between different groups of users.

After some weeks, it turned out that parents did not use Baby Watch as much as expected. The script of the Baby Watch system was adjusted to remove one of the most important restrictions, the parents' dependence on the nurses to start up the system. In the second prototype of the Baby Watch, the camera was installed permanently at the baby's incubator, and the parents did not need to phone the nurses in order to use the Baby Watch. From that moment on, the parents could watch their baby whenever they wanted, without the intervention of the nurses. However, now control of the images was not delegated only to the nurses, but also to a lid that could cover the camera while the baby was being treated. The responsibility for the lid was fully delegated to the nurses. If, for instance, they forgot to remove the lid after treatment, the parents could potentially become anxious as they tried to see their baby. After these changes, however, the popularity of Baby Watch among the parents clearly increased.

Compared with the first product, the second product, VIATV Phone, had two distinctly new features: first, the computers (laptop as well as the server) were replaced by a TV and a little box that connected the TV to the phone; and second, the system allowed parents more control of the images. The script of this second product is very similar to the second prototype of the Baby Watch: responsibilities and control are still largely delegated to nurses. When parents started up the VIATV system, the nurses had to react to the signal and commence communication by lifting the telephone. At that moment, they also checked the position of the baby and the quality of the images. The nurses' responsibility for covering the camera with a lid during treatment and uncovering it after treatment did not change. However, the script of the VIATV Phone shows less-restricted agency for the parents with respect to controlling the images. They could choose between moving or fixed, clear pictures, they could operate a zoom lens, and move the camera (to a limited extent). Just like

Baby Watch, the VIATV Phone system does not broadcast sound. Although the VIATV technology does allow the functionality of transmitting sound, this option was ruled out here by disconnecting the sound wires in the camera. Thus, the control of sound from the hospital to the parents' home was, in fact, fully localised within the disconnected wires. Since the VIATV system is interactive, it also enables the hospital to receive images from the parents' home. The responsibility for controlling these images was not realised within the technology but was delegated to the parents. Parents were advised to point the camera at the wall to prevent pictures being sent from their living room to the hospital. Thus, there is a clear asymmetry in the way the VIATV Phone script delegates the control over the hospital's privacy and the parents' privacy.

The VIATV Phone is the final stage in the development of the video-communication system in neonatology. However, this video-communication system also turned out to be an interesting technology for other user locations. Royal Dutch Telephone decided to develop a new product based on the same technology as VIATV, the so-called "Magic TV", to be used in the children's oncology ward. Although we shall primarily focus our analysis on the products designed for the neonatology ward, Magic TV is relevant to our analysis as it allows us to visualise the specific scripts that were built into the VIATV Phone system used in the neonatology ward. In contrast to the way the VIATV Phone system is used in the neonatology ward, Magic TV offers the possibility for *symmetrical* communication between the two locations. It is a fully interactive system transmitting images as well as sound, allowing both sides to control the connection and the images. With Magic TV, the cancer patients can continue to interact with their friends, family and school during hospital treatment. Compared with the previous two products, the Magic TV script delegates much less control to the nurses and, again, more autonomy to the parents and, most importantly, to the children.

As we have seen, the various video-communication systems contain quite different scripts in terms of distributing agency, control, and responsibility among people and things, and among the different user groups involved. To understand how these scripts were generated, we shall focus on the design process.

## Designing scripts: The co-production of an artifact and its users

We shall analyse the developmental process of the video-communication system from two perspectives. First, we look at the way in which the different actors involved in the design process represented the envisaged users. After all, it is these notions of the user that are objectified into design choices and thus constitute the script of the artifact. But who is the user? In fact, the designers and other actors involved in the development of this new artifact actually considered four different groups of users: the parents, the nurses, the management of the hospital, and the baby. Which representations were made of these user groups? Which techniques were used to represent the users? Second, we look at the way the diverse user groups were able and were allowed to influence the design process. This is really a question of those directly involved by the designers in the design process, but we can go one step further. Since the developmental process of the video-communication system was characterised by a succession of different prototypes that were actually put into use, we are able to question how the distribution of agency, control, and responsibilities in the socio-technical configuration around one prototype may have influenced the design and the script of the next one. The iterative succession of design and use allows us to trace differences between the user representations and the actual user, and to analyse whether or not these differences or mismatches shaped the future design.

A first glance at the design process reveals that there are important differences in the ways in which each group of users was represented in the design process. Whereas nurses and the hospital management were directly involved in decisions shaping the design, because representatives of these groups were part of the committee that was installed to guide the design process, the parents and the babies were represented by nurses and the hospital management, who were entitled to act as spokespersons for these users. Thus, the parents (and babies) were not granted agency to contribute to the negotiations on the design, because the hospital manager and the senior nurse assumed that they would not want to worry about anything else other than their babies. They did not consider an alternative representation of the parents, and decided that the nurses were sufficiently informed on the positions of the parents to represent their preferences and interests. The account manager responsible for the interaction between the hospital and Royal Dutch Telephone did not make an issue of the absence of parents on the committee. As a result, the project committee consisted of three nurses, the head of the neonatology ward (a senior nurse), a doctor, and a representative of Royal Dutch Telephone called "the human-factor specialist", who acted as the project co-ordinator and served as the intermediary between the hospital and both the technical designers and software engineers.

*Parents*

The fact that parents were not considered as relevant actors for participation on the project committee implied that the designers had to rely on other sources to assess the needs and preferences of the future end-users. The design process of the first prototype shows that parents were not consulted at all. The engineers only applied informal techniques to represent the user.[4] In contrast to what one might expect, informal techniques are widely used in many Information and Communication Technology companies (Oudshoorn 1999). In the case of the Baby Watch project, the major representation technique consisted of inviting others to speak for the users. In this case, nurses were considered adequate spokespersons for the parents. Since nurses had frequent contact with parents on the neonatology ward, they were expected to be able to assess the needs of the end-users. The nurses, too, regarded themselves as adequate spokespersons for the parents: "We thought we knew what they wanted".[5]

Another representation technique frequently used in the design of the first prototype was the so-called I-methodology: engineers used their own ideas and experiences as a first user of computers to generate a representation of the future user. The dominance of these informal representation techniques had a major impact on the script of the first prototype. The user images constructed by the nurses as well as engineers show a very specific representation of the end-users, including a specific assessment of the skills they were expected to have to operate the new artifact. Nurses and engineers represented the parents as computer illiterates: parents were expected to have no experience with computers or ICT products at all. This was precisely the reason why Royal Dutch Telephone considered the development of this new artifact as relevant enough to include it in their R&D agenda. The challenge the designers expected to face was "to develop a computer that did not look like a computer".[6] At that time, only 50 per cent of the Dutch population were familiar with computers, and Royal Dutch Telephone expected that not all potential end-users of Baby Watch would be capable of handling a PC and the corresponding software program. Baby Watch thus provided a convenient experimental site to explore the conditions and technical features of a computer system that had to be made as user-friendly as possible. The image of users as computer illiterates functioned as an important element in shaping the technological decisions and the script of the system. Based on this user image, the Royal Dutch Telephone decided to design a product that could be operated with a simple click. A second feature of this first prototype shows that designers also actively configured a non-user. Both Royal Dutch Telephone and the hospital management did not want any interference from outside, so the designers developed a system that was protected against the more sophisticated user. The result was a fast-running system that could be operated with an on/off switch, but without any possibilities for further action by the users.[7]

Although designers thus put a lot of effort into making a computer that they considered capable of matching the needs and skills of the end-users, the reactions of the parents to the first prototype show a clear mismatch between the presumed attitudes of users towards computers, as represented by the nurses and the engineers, and the actual attitudes of the real users. Whereas engineers and nurses did not consider the *computer itself* as a possible stumbling block for the end-users (making the computer user-friendly was considered sufficient to solve the expected problem of lack of computer experience), parents turned out to be very reluctant to use the computer at all. During the first weeks of the introduction of Baby Watch, only a handful of parents could be convinced to take the laptop home. In this experimental stage, every week it was difficult to find a parent who wanted to use Baby Watch. Whereas the Telephone Company and hospital management presumed that the Baby Watch would stimulate the quality of the child-parent relationship, many parents were not easily convinced of the usefulness of this kind of communication. Moreover, they saw it as a redefinition of the parental relationship by introducing a technical artifact into the relationship with their vulnerable child. Despite the fact that engineers had put a lot of effort into making the computer as user-friendly as possible, it was, nevertheless, still a computer.

A few weeks after the introduction, the parents were given a voice for the first time via a small questionnaire that was developed by the project co-ordinator. This questionnaire made it very clear why parents were reluctant to use Baby Watch: they feared that the system might create too-remote a relationship between themselves and the baby. Although the questionnaire did not provide information about the ethnicity of the parents involved, the nurses did experience an ethnic disparity. Parents from a non-Western background were more reluctant to use Baby Watch. The nurses felt that, within these families, Baby Watch was considered as an unwelcome, technical intruder into their homes.[8] To them, some spheres of life should not be "technologised" – especially the area of love and vulnerability. To make Baby Watch acceptable to these parents, the designers had to mask the technological image of the artifact. The fact that the TV was acceptable to a wider group of the parents shows how this device is no longer considered as technology. Over the last few decades, the TV has witnessed such a rapid dissemination (most Dutch families, including immigrants, have a TV in their living room) that the artifact has lost its technological image. This is obviously not the case with the computer. Differences in attitudes between different cultural groups towards technology had not been anticipated by the engineers.

The questionnaire also informed the designers and the nurses about the barriers parents experienced using Baby Watch. The parents experienced the access to the system as a major barrier to using Baby Watch. The script of the first prototype delegated access responsibilities to the nurses who functioned as gatekeepers. Parents had to phone the nurses in order to operate the system, and despite the fact that parents and nurses had a tradition of making phone calls concerning the well-being of the child, this seemed to be an extra obstacle. Many parents, especially mothers, wanted to watch their child late in the evening and during the night, not quite the time to disturb nurses with a telephone call. Or, as the project co-ordinator concluded: "To ask permission for a video connection unconsciously seems to put up a barrier for the parents". In this respect, there were major differences between the preferences of users as imagined by the designers and the preferences of the actual users. As a result, the system was adapted to the parents' behaviour. Whereas the first prototype operated only on stand-by, the second prototype of Baby Watch worked on a permanent basis and thus increased the parents' agency and control. This was the first time that users, i.e., the parents, had an impact on the actual design of the new technology.

Another mismatch between the users as represented by the designers and the actual users concerned the design choices about the ways in which images should be presented on the screen. At that time, the system was not sophisticated enough to produce clear running pictures, so the designer had to choose between two kinds of application: a clear picture with little movement, or a moving, but more vague image. Relying on the I-methodology, the designer chose a clear picture. Both the engineers and the account manager preferred to have a good view, and they assumed that parents would have the same preference because they would like to recognise their baby. Or as the account manager stated: "We expect the users to demand the same quality as we do".[9] The parents, however, wanted to see their children move, more or less as a sign of health. In the second prototype, the designers therefore adapted the design of the screen to enable parents to select whether they wanted a clear picture or a moving picture. This was the second time that parents exercised an influence on the design.

The design process of the first prototype thus exemplifies the risks that are involved in relying on informal and indirect methods of assessing the needs and skills of users. In a constellation in which all the information is mediated by other agents, spokespersons, and representations, designers run the risk of losing crucial information. In this case, this covered information on user preferences for a specific type of artifact (i.e., TV rather than a computer), information on the user needs in a medical context, and the social preconditions for using the artifact (the relationship between nurses and parents). In this respect, the design of Baby Watch was an exceptional experience for the Royal Dutch Telephone engineers. Usually, ICT products are designed for professional users or for fun – think of the many digital ICT games that have been developed over the last decade. By developing Baby Watch, engineers entered a completely different world where the people using ICT products are experiencing sorrow and grief rather than pleasure or work. Engineers could not anticipate these differences because they had no contact with the parents and did not visit the neonatology ward during the development of the first prototype. It was only during the development of the second prototype that one of the engineers visited the hospital, and this is how he described his experiences:

> Suddenly, you realise that this is a completely different world. Here are people with sorrow and grief, they are not sitting and waiting for a new toy. For them, all that matters is the child. This was a dramatic experience for me. We could have known this, but we did not think about it. We are primarily engaged with the technology.[10]

Reflecting on his experiences with the design of this new artifact, the account manager came to a similar conclusion. Due to technical problems with Baby Watch, the account manager visited the parents at home, which provided new information on how to solve technical problems with the PC and the transmitter. Visits to the location of use and consulting the parents via questionnaires were thus only introduced *after* the development of the first prototype.

### *Babies*

Just like the parents, the babies were also represented in the design process by spokespersons. There is, however, an important difference between parents and babies. Whereas parents are able to take part in the design process without mediation by spokespersons, babies cannot speak for themselves. They are dependent on spokespersons to communicate with designers and represent them in the design process. In the design of Baby Watch, nurses and hospital management acted as spokespersons for the babies. Nurses represented the baby by articulating their worries about possible negative consequences of the introduction of Baby Watch in the neonatology ward. The nurses considered regular visits from the parents to be important to the well-being of the child. They feared that the introduction of Baby Watch would reduce the visits of parents to the hospital because they could simply stay at home and observe their child. The hospital management also acted as spokesperson for the baby, but constructed the opposite image: babies in incubators would benefit from Baby Watch because the device would facilitate the bonding between parents and babies. During the first months after the introduction of Baby Watch, this representation of the baby as someone who benefits from Baby Watch became the dominant image, which was accepted by nurses as well. Most importantly, the frequency of the actual visits did not decrease after the introduction of Baby Watch. Gradually, all the actors involved in the design process began to emphasise the benefits for the baby as well as the parents, referring to the positive responses of the parents and the ways in which Baby Watch played a role into integrating the baby in everyday life. The pictures of the babies were shown to siblings, grandparents, neighbours, friends, and people who generally do not come to a hospital. As a result, so it was concluded, the virtual babies became part of family life. One mother stated: "It is comforting to be a complete family for a while".[11] Besides the Royal Dutch Telephone account manager, there was also one of the nurses who emphasised the importance of Baby Watch for fathers: it would enable them to do something with the child and create a new way for men to deal with the situation. The image of the baby as profiting from Baby Watch thus played an important role in articulating the need and legitimising the introduction of Baby Watch in the hospital.

In addition to this legitimising function, images of the baby also figured in the various phases of the design process. The covers of two textual devices included pictures of the baby. The report published by Royal Dutch Telephone Research describing the experiences with the first prototype of Baby Watch includes an intriguing image of the baby: the baby is depicted as the user of Baby Watch. The cover shows a cartoon of a happy baby in diapers (the hair and the facial expressions suggest that it is a male baby) using a laptop, sitting next to a teddy bear. The manual of the VIATV Phone system displays a strikingly different image of the baby. The cover shows two photographs: one of a baby lying on its stomach under a small blanket in the incubator, his/her face turned to the viewer. The second shows a man and a woman watching a TV showing a baby in an incubator. They are both smiling, and the woman is pointing to the baby on the screen. These images of the baby reflect the differences in the representation techniques used in various phases of the design process. The image of the playful baby exemplifies the distance between the world of R&D and the location of use that dominated the early phase of design. As we have described above, visits by the designers to the site of use, i.e., the hospital and the home of the parents, only took place in a later stage of the design. The more realistic image of the baby on the cover of the Via TV Phone manual (realistic because they are photographs instead of cartoons, and portrayed the baby in the incubator rather than as a computer user) reflects a less remote relationship between the worlds of design and use.

The baby finally, figured into the design process when designers had to decide on the quality of the images of the baby on the screen. The specific circumstances of the incubator caused several technical problems. The incubator's white sheets had a particular influence on the camera's exposure. At this point in the design process, the baby was constructed as a patient, and the actual configuration of the situation was primarily oriented towards medical treatment. The camera had to be adjusted to this situation and so it was positioned in such a way that it would not interfere with other medical devices near the incubator. Moreover, the camera was designed to be very flexible and easy to handle by the nurses whenever the baby needed medical treatment. Again, the nurses acted as spokespersons for the babies.

### *Nurses*

In contrast to the parents and babies, the nurses were more directly involved in the design process. As we described above, the senior nurse, and head of the neonatology ward and three other nurses participated in the project committee that attempted to control all stages of the design. Actually, the nurses performed three distinct roles in the design process. First, nurses acted as users. To them, the introduction of Baby Watch implied that they had to deal with a new and permanent element in their working environment. They had to take care of the babies in a highly technologised environment in which an additional device had been introduced, implying a change in their daily routines. As we have described above, the Baby Watch script delegated most of the responsibilities to the nurses who had to operate the system whenever the parents called, and they became responsible for a new form of "baby management" ("never lay a baby down in the wrong incubator!") as well as for the transmission of images. Second, the nurses played a crucial role in the dissemination of the new apparatus. It was their task to introduce Baby Watch to the parents and to give instructions and explanations on how to use the equipment. This was a new and complicated job because nurses had to negotiate with parents in a period in which the latter were overwhelmed by emotion and possibly grief and sorrow. To make things even more complicated, the nurses were rather ambivalent about Baby Watch because they thought the new technology might have a negative influence on the physical visits of the parents, as we described above. By involving the senior nurse in the design process, the designers were able to anticipate the ambivalence and possible resistance of nurses towards the new technology. Third, as has been described above, nurses functioned as spokespersons for the parents. In this case, the nurses acted as strong agents, as powerful actors.[12]

Because of these different roles, nurses became an "obligatory point of passage" for the designers, to use Bruno Latour's terminology, which explains why they were allowed to take part in negotiating the technological decisions (Latour 1987). Communication with the nurses was crucial for the designers: because the nurses provided them with information about the work floor and about the parents, and last but not least, they had to interest the parents in the new technology. The motivation of the nurses was essential to the success of the experiment because if the nurses did not want to work with Baby Watch, the technology would totally fail. This position enabled nurses to negotiate changes in the artifact to make the new equipment more convenient to use. In the second Baby Watch prototype, the inflexible camera was replaced by a flexible one as a reaction to complaints from nurses about the inconvenience of the fixed camera during the nursing of the babies.

### *Hospital management*

Like the nurses, hospital management was also involved in negotiating technical decisions, although it did not participate in the special committee. This responsibility was delegated to the doctor who also had a seat on the committee. Although the designers considered parents as *the* users, the Royal Dutch Telephone project manager considered hospital as his primary customer. After all, it was the hospital that was paying for his company's services. The role of this fourth user became very crucial when the hospital manager first became alarmed by the unexpected consequences of the new technology. It was during an interview with the press that a journalist asked the manager of the hospital about possible abuses ever of Baby Watch. The recording of transmitted pictures could provide the parents with evidence if they ever wanted to start a legal process regarding the treatment of the baby. This unforeseen consequence produced a shock within the ranks of hospital management and elicited a new image of the end-user. Parents were suddenly portrayed as potential troublemakers because they could begin legal proceedings against the hospital regarding the treatment of their baby. As a result, the hospital management forbid the transmission of any images showing medical treatment. Consequently, new instructions for the nurses were formulated: during every medical treatment or nursing of a baby, they had to cover the camera with a lid, not only for the peace of mind of the parents, as nurses initially told us, but also in the general interest of the hospital. For the same reasons, and on the basis of another argument – the privacy of other patients and parents – the transmission of sound was not an option in both the Baby Watch and the VIATV Phone systems. In the latter system, the sound cable was physically removed. In the case of Magic TV, used in the child oncology ward, the hospital management controlled the "virtual boundaries" of the hospital by using a separate room for video communication. Obviously, in the neonatology ward, this is impossible. The intervention of the hospital management thus resulted in a drastic change in the design of the VIATV Phone system.

### *Agency in influencing design*

Our study shows how multiple users were engaged in the design process, albeit in different ways. The nurses and hospital management had direct access to the design process; they could mobilise sufficient resources in order to influence the actual design and implementation of Baby Watch. The parents and babies, however, only took part in the design process indirectly. Their interests, wishes, and skills were assessed by spokespersons who acted on their behalf: the designers, the human-factor specialist, the account manager of Royal Dutch Telephone, and the nurses. They all had their own representations of the parents and the parents' wishes regarding their babies and/or Baby Watch. The parents themselves were interviewed only after the first prototype of the Baby Watch was introduced, which revealed that the representations of the users did not match the actual preferences and skills of the real users. Interestingly, the extent to which user groups were engaged in the design process is not congruent with the impact these groups had on the actual design. Although the nurses had direct access to the design process, their actual impact on the design was rather limited – only the design of a flexible camera was clearly influenced by the nurses' wishes. Only the babies had less impact. They shaped the design only indirectly through their parents' preference for the quality of the images on the screen, thus altering the design to include both moving and fixed images of the baby.

In comparison to the babies, the parents had a much larger impact on the design. Their resistance to using the initial Baby Watch prototype was a powerful influence on the characteristics of later artifacts: the system had to be open up to them on a permanent basis, and the "technological image" was masked by replacing the laptop with the more familiar TV. Clearly, a substantial group of parents did not accept the script of the initial Baby Watch prototype. By rejecting the script, and thus becoming non-users, they motivated designers to change the design. The "talking back" of the users (Epstein 1996) resulted in the development of a new prototype. Although rejecting the script should thus be considered an important means to influence design, non-use does not guarantee that designers will adjust their designs to the wishes of end-users. The deterring influence of the technological image of a laptop, particularly with regard to ethnic groups, was judged by the designers to be an essential shortcoming of the system. However, the VIATV Phone system, in turn, also created non-users, although this group differed from the Baby Watch group. In the case of the VIATV Phone, parents rejecting television on religious grounds were among the non-users. Strikingly, this type of exclusion was evaluated as being of "their own choice" and did not lead to design changes.[13]

Finally, hospital management played an important role in the technological decision-making because they set the conditions of and the limitations to the transmission of signals and sounds. Their decision not to transmit sound overruled the interests of the parents. In negotiations on the design, the hospital manager's demand for limited access and transmission was more effective than the parents' wishes for open access. Although the designers considered the parents as the actual end-users, the technical decisions on what the new technology would eventually communicate to the parents were predominantly shaped by the demands and interests of hospital management. Its dual role as user and customer facilitated a situation in which Royal Dutch Telephone granted the hospital's preferences more authority than the parents' wishes.

## Conclusion

Our script analysis of the various prototypes of this video-communication system illustrates how artifacts play an important role in delegating and distributing agency and control among the various users. The three artifacts used in the neonatology ward (that is two prototypes of Baby Watch and the VIATV Phone) acted quite differently with respect to the way they distributed agency between different groups of users, i.e., parents and nurses, and between users and the artifact itself. Whereas the first prototype of Baby Watch delegated all responsibilities and control to the nurses and only limited agency to the parents, the second Baby Watch prototype delegated more agency to the parents. The VIATV Phone system increased the agency of the parents further by adding the ability to control the image, although the parents still depended on the nurses to use the system. Most importantly, the parents were denied the ability to receive or send sound.

Our analysis thus suggests that the concept of distributed agency is an adequate tool to show that technological artifacts can contribute to an asymmetry in agency and control over technologies among heterogeneous groups of actors, human as well as nonhuman. The concept of distributed agency, however, does not perform very well if we want to understand the processes underlying the design of asymmetrical scripts. Whereas actor-network approaches emphasise the conceptual symmetry between human and nonhuman actors, this case study shows asymmetry: asymmetry between people and artifacts and, more importantly, asymmetry between various human actors. The problem is that the emphasis of actor-network theory upon the symmetry between humans and nonhumans tends to obscure asymmetries between human actors.[14] Moreover, actor-network theory neglects an important conceptual difference between human and nonhuman agency. Although both people and artifacts can act, only humans can be held responsible for the technologies they produce. One cannot hold objects accountable for their actions – or perhaps one can, but this will not result in changes in design practices that create asymmetrical scripts. Most importantly, our case study shows that asymmetrical scripts are not the result of the agency of nonhuman actors but originate from human decisions. The agency of parents to operate and co-produce the video communication products remained relatively limited, not because of technical constraints but because of negotiations and power relations between the different actors involved in the design process. Hospital management overruled the possible interactivity of the artifact by adding a camera lid and by disconnecting the camera's sound cable. This decision overruled the interests of the parents. In accordance with the existing literature on the influence of the various user groups on design processes, we found that the end-users were assigned less agency than the other groups involved in the design process (Berg et al. 1999; Lehoux et al. 1999; Clarke and Montini 1993).

We therefore conclude that, in contrast to what Latour suggests, actions do have a point of origin (Latour 1996[a], 237-8). In our case study, hospital management and the designers could mobilise resources to boost their own interests in the design and implementation process. Their interventions restricted the possibilities of the technology and the possibilities/agency of the parents, but only the latter were in a position to react directly to interventions. They did not like the technology of the first prototype and were reluctant to use it as a means of communication with their babies, which forced the designers to adapt the system. This kind of more or less deliberate action is human-based.

At this point in the analysis, the usefulness and analytical strength of the concept of symmetry between human and nonhuman actors comes to an end. Our study shows that "symmetry" is primarily a very useful analytical instrument but also that, in many cases, human actors make the difference. To be able to answer questions concerning the politics of technology, we need to acknowledge that, ultimately, human and nonhuman agencies do not coincide and should be considered as different entities.

## Notes

1 Latour (1996[a]) defines this in his article "On Interobjectivity" as "to act to mediate another's action". Later, in his reply to critics, he again distances himself from the concept of mediation.

2 In 1998, we organised a workshop for the Royal Dutch Telephone Company, the erstwhile market leader in communication technology in the Netherlands. The workshop aimed to discuss user-oriented design processes and the actual design practices of Royal Dutch Telephone. We decided to take one case and reconstruct the design and implementation process, and the way users were configured and engaged in these processes. Baby Watch seemed to be a useful case study because the technology was developed for multiple users, and different user groups were involved in the design process. Before the workshop, we interviewed the relevant staff members: the account manager, the human-factor specialist, and the software designer. In addition to the interviews, we used several reports written by Royal Dutch Telephone during the design of this video communication system.

3 Interview Royal Dutch Telephone account manager, February 5, 1998.

4 See Akrich (1995) for this distinction between implicit, informal techniques and explicit, formal techniques to assess user needs. Explicit representation techniques, such as marketing surveys, consumer tests and feedback from users through after-sales services, are legitimised by formal, scientific bases, whereas informal techniques lack this basis. Examples of the latter are reliance on personal experience, on the consultancy of experts, and on user images incorporated into earlier products.

5 Interview with the head of neonatology, January 27, 1998.

6 Interview with a designer from Royal Dutch Telephone, February 5, 1998.

7 After some months, the interface became a little more complex, since the system was used in locations where the pre-installed telephone number did not work, e.g., in Germany and internally in the hospital. The parents first had to work through some menus before they could start the system.

8 Interview with the head of neonatology, January 27, 1998.

9 Interview with the account manager of Royal Dutch Telephone, February 5, 1998.
10 Interview with a designer from Royal Dutch Telephone, February 5, 1998.
11 This representation of the family and the baby was also included in some of the newspapers which reacted to the press report launched by the Radboud Hospital after several weeks of using Baby Watch (Anonymous 1996; Knol 1996).
12 Until recently, sociological research on hospitals displayed a rather surprising absence of nurse-related information, although their work is part of the core business of medical organisations. Research from a gender perspective revealed the importance of the nurse as a powerful actor within hospitals (see, for instance, Davies 1995).
13 Interview with the head of neonatology, January 27, 1998.
14 A similar critique has been articulated by other scholars, most notably Adele Clarke. Clarke has introduced the concept of "implicated actor" to avoid silencing invisible actors and to include power relations in the analysis of user-expert relationships. This concept includes two categories of actors: "those not physically present but who are discursively constructed and targeted by others," and "those who are physically present but who are generally silenced/ignored/made invisible by those in power". (Clarke 2004; see also Clarke and Montini 1993; Clarke 1998). Our case study exemplifies the second category.

# The Mediation of Agency

# Choices and Choosing in Cancer Genetics

*Dirk Stemerding and Annemiek Nelis*[1]

## Introduction

Clinical genetics has established itself as a medical practice in which patients are addressed primarily as individuals who have to make informed choices (Bosk 1992; Steendam 1996). Historically, centres for clinical genetics in the Netherlands have a privileged position in offering genetic counselling and genetic testing, and function as "gatekeepers" for those seeking genetic consultation and diagnosis (Nelis 2000). In these centres, genetic diagnosis is embedded in a practice of counselling in which facts deemed relevant are separated out as "information" that is handed out to clients along with a few courses of action formulated as possible alternatives and between which clients are requested to choose. The establishment of clinical genetics thus created a particular space for individual decision making in which, from the 1990s onwards, new options for genetic testing on the basis of DNA-diagnosis have been introduced and evaluated primarily as bringing along new opportunities of choice (Bourret et al. 1998).

In today's health care, this particular configuration – that of the individual patient called upon "to decide" – is held in high esteem. A good doctor leaves patients room for choice. But how can we understand the issue of individual choice when we simultaneously consider the rapidly developing practices of medical genetics from a perspective of *co-production* of technology and society? From this perspective, we are interested in the question of how technological objects and individual subjects – nonhuman and human agents – mutually shape one another in an emerging web of socio-technical relations (Berg and Mol 2001). Looking at recent developments in medical genetics in this way, we can make two observations. We see the emergence of increasingly complex networks, involving a growing interdependency between many different actors: technologies of screening, registries, medical specialists, patients, clinical genetics centres, and individuals at risk. At the same time, we see how in this network a particular model of human agency is endorsed, according to which it is the individual patient or person at risk who has to decide.

How should one weigh these observations? Should we interpret them as revealing a tension or even contrast between "structure" – embodied in networks and interdependencies – and "action" – embodied in individual freedom of choice? Or should we understand the model of individual decision making as a particular outcome of a process of co-production of technology and society? Framed in this way, our observations invite us to go beyond "an oscillation in social analysis between action as determining and action as determined" (Gomart and Hennion 1999). That is, we are invited to shift the analysis to the collective production of human agency, to the creation of particular subject positions as an effect of emergent socio-technical networks.

In this chapter, we attempt to take up this invitation in an analysis of how subjects and responsibilities are constituted in new emerging practices of screening in the field of cancer genetics. We focus our study on the way in which in the Netherlands a screening practice has emerged for familial adenomatous polyposis (FAP), a specific hereditary predisposition for colon cancer. First, we shall show how in the 1980s a regular screening practice was created which involved both patients and "individuals at risk". Then we describe how this screening practice was extended with new elements, with the development and introduction of DNA-diagnostic tests, involving new choices and responsibilities. Thus, we shall cover the way in which responsibilities were distributed and human agency was shaped in these various contexts. In conclusion, we shall discuss our findings in the context of current debates about patient autonomy and freedom of choice in today's health care and the emerging new genetics.

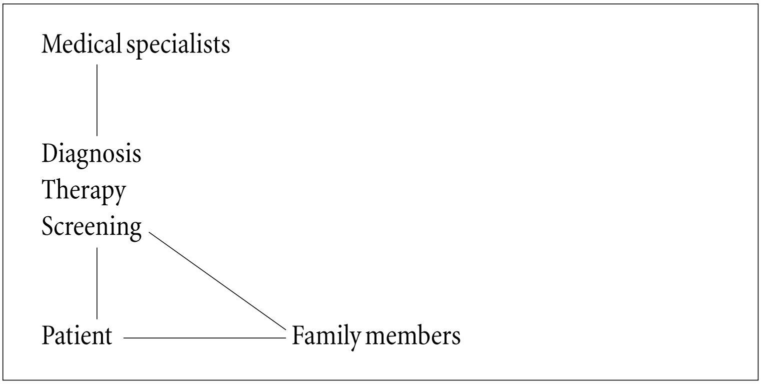
## FAP in the early 1980s: the emergence of a screening practice

In 1981 a collection of three articles and a commentary appeared in an issue of the *Dutch Journal of Medicine*, which focussed on the clinical experiences involving a rare, dominantly hereditary disease, called polyposis coli or familial adenomatous polyposis (FAP). In each of the three articles, an elaborate description was given of the history of the disease in a particular family. One of the articles opened with the story of a 27-year-old woman who consulted the clinic because a 34-year-old cousin of hers had been recently identified as an FAP patient after the diagnosis of colon cancer (De Ruiter and Den Hartog Jager 1981). The mother of the woman had died of colon cancer when she was

43, a few years after the colon had been partially removed because of a malignant polyposis. The authors of the article observed with regret that clinical examinations of relatives had not been undertaken at the time, although it was known that a grandmother and a great-grandfather had also died from "cancer of the colon". The woman who was consulting the clinic had no symptoms, but inspection of the colon revealed many polyps resulting in a subsequent diagnosis of FAP and in the decision to completely remove the colon. The article then continued with the case of a younger sister of the woman, who similarly displayed no symptoms, but who also had her colon removed after investigation had indicated polyposis. Other brothers and sisters examined only revealed a few polyps in the colon. In these cases, as the authors point out, the examination had to be repeated every year. In conclusion, the article reports the results of examinations that had been carried out on 39 people, spanning two generations of the family. Polyposis was found in 12 cases, and colon cancer had already developed in 4 of them. Four people refused the invitation to undergo examination.

The collective publication of the three articles and the accounts given by the authors of the diagnosis, treatment and screening in families where FAP is found may be seen as an event which marks the emergence of a specific clinical practice, i.e., a practice in which the professional responsibility of the medical specialist – an internist or gastro-enterologist – cannot be restricted to the individual patient, but should also extend to the health and survival of the patient's relatives (see figure 1 below). When a patient finally consults the clinic with specific symptoms and the diagnosis of FAP is made, in most cases a fatal colon cancer will have already appeared. Thus, as the authors of the articles point out, it is of vital importance to trace the families in which FAP is found and to screen the members of these families every two or three years,

*Figure 1: Emergent cancer genetic practice in the field of polyposis (late 1970s)*



beginning from about the age of ten. As soon as more than one hundred polyps are found in the colon, the diagnosis of FAP should be made, and it is only by complete removing the colon that the development of cancer can be prevented. Even then, regular screening remains necessary. If, on the other hand, family members are still free of symptoms between the ages of forty and fifty, the appearance of polyposis can be reasonably counted out, and screening may be terminated.

The conclusions and recommendations of the authors were clearly intended to promote a practice that, at the beginning of the 1980s, was still in its infancy. At that time, it was already considered against due practice to refrain from an extensive family anamnesis when the diagnosis of FAP had been made. However, in the preceding period, this kind of family anamnesis was by no means the rule, which is explained, in one of the articles, by a general lack of knowledge of the serious consequences of the disease. Even when an extensive mapping of the family history of the patient followed the diagnosis of FAP, it was often considered to be an impossible task for the individual specialist to actively approach all the family members involved. And, as far as family members were actually approached, the specialist could not always be sure that they would return regularly for periodic screening. Thus, in a commentary on the three articles mentioned above, published in the same issue of the *Dutch Journal of Medicine*, it was observed that:

> Detective-like genealogical investigations, the psychological burden experienced by people who feel completely healthy and yet face the prospect of invasive examinations of the colon, and the not always interesting task to screen a fairly large number of people who have no symptoms, require a great and unremitting enthusiasm and dedication of those who undertake to follow a family with a history of polyposis. (Van Slooten 1981)

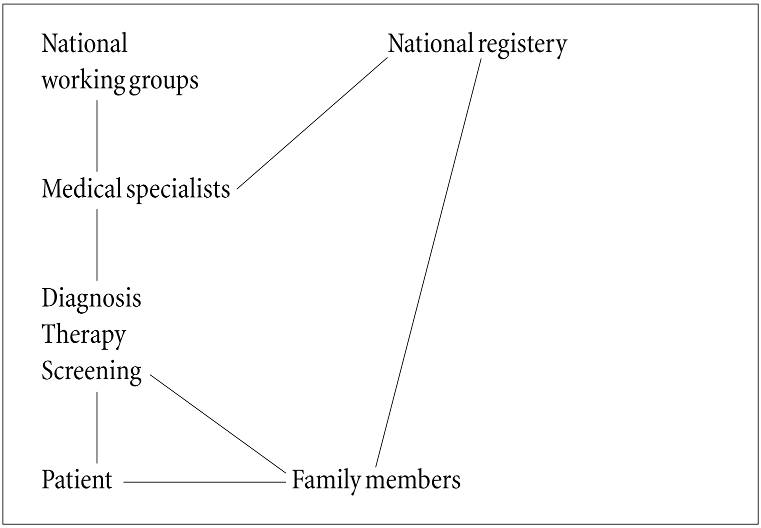
Hence, the author of the commentary argued for the establishment of a centralised national registry, which could send out a reminder to medical specialists each time a person at risk had to be called in for screening. The results of the screening were to be returned to the registry. If no results followed, the organisation could take further action in order to safeguard the care for those at risk and to obtain certainty about their conditions. With his plea, the author actually repeated a message that he had already voiced in the same journal no less than 25 years earlier. This time, however, the argument would find an audience.

### Late 1980s: The establishment of a national registry

At the end of the 1980s, a patient consulting a clinic with symptoms of FAP would encounter a practice that was indeed different from what we have seen earlier. The medical specialist in attendance now not only had to inform the patient about the hereditary nature of the disease and the importance of screening family members, but also could refer the patient to the national *Foundation for the Detection of Hereditary Tumours*. In 1983, this foundation was established by a number of specialists involved in the treatment of patients and their families suffering from hereditary tumours (one of the founders was the author of the commentary quoted above). In 1985, the Foundation started a national registry of families with a history of FAP, thus aiming to promote screening in high-risk families, to guarantee the continuity of screening, to collect data for scientific purposes, and to offer advice about the diagnosis, treatment, methods of screening, and genetic services for counselling (Vasen et al. 1988).

The result of this development was a more extended practice of diagnosis, treatment and screening of FAP, in which every patient is reported by medical specialists to the Foundation for the Detection of Hereditary Tumours (see figure 2 below). A social worker at the Foundation then approaches the patient and with his or her help draws up a family tree which makes it possible to trace the history of the disease and to identify members of the family who are at risk. The patient is asked to inform relatives at risk and to urge them to have

*Figure 2: Establishment of a national registry in the field of polyposis (late 1980s)*



themselves screened. If they agree, family members are approached by the Foundation with a request for registration. In this way, nearly all FAP families in the Netherlands have been registered, amounting to a few hundred (Annual report 1994). Personal and medical information is collected from those who have registered, and through a system of reminders, specialists are notified when individuals should be called in for screening. If no screening results are reported, and upon inquiry it appears that someone did not turn up for screening, the registry will send out a request to the family doctor to take action and to remind this person that screening is of vital importance.

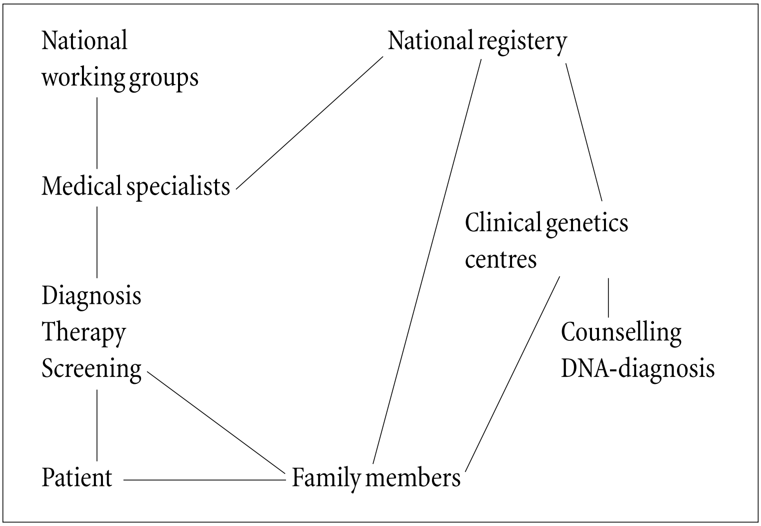
While the care of individuals with a risk of FAP initially strongly depended on the enthusiasm and efforts of individual specialists and on the awareness of those at risk, it is now the Foundation for the Detection of Hereditary Tumours which has assumed the responsibility for the organisation and continuity of screening and which "will put all efforts into encouraging (registered) individuals to comply (with regular screening)" (Annual report 1994, 5). Indeed, as those working at the Foundation point out, in order to motivate family members to participate in a screening program, good information and a personal approach including home visits are necessary (interview data, see footnote 8). Moreover, through the establishment of a national registry, information is collected which not only facilitates the organisation of a screening program, but which also creates possibilities for a systematic follow-up and an evaluation of its results. For that purpose, two national working groups on FAP, involving various forms of expertise, collaborate with the Foundation in the organisation of studies and the establishment of guidelines (Vasen et al. 1988). Thus, through the efforts of the Foundation, local practices of early detection and prevention have become part of a larger network in which these practices are organised and regulated on a national scale.

### Early 1990s: The advent of DNA-diagnosis

In the early 1990s, a patient who consulted the clinic with FAP symptoms would again encounter a practice that had been extended with new elements – new technologies, rules and organisations (Vasen and Müller 1991). In 1991, molecular biologists succeeded in relating the occurrence of FAP to mutations in a particular gene, the so-called APC (adenomatous polyposis coli) gene. This finding made available the possibility of presymptomatic DNA-diagnosis whereby members of an FAP family could be informed about their individual riskstatus on the basis of mutation analysis, that is, whether they will get the disease or not. However, in the Netherlands, DNA-diagnosis is made available only through a network of regional clinical genetics centres. Thus, with the advent of the DNA-diagnosis of FAP, molecular biology laboratories and clinical genetic centres became part of the network in which the practice of diagnosis, treatment, and screening of FAP took shape (see figure 3 below).

A new patient will now not only be reported by a medical specialist to the Foundation for the Detection of Hereditary Tumours, but will also be referred to a clinical genetics centre for mutation analysis. Again, a clinical genetic centre counsellor will draw up a family pedigree in order to identify relatives who may be at risk of developing the disease. Family members of the family then have the opportunity (after being been informed by the patient) to be referred to a clinical genetics centre, which may offer them presymptomatic DNA-diagnosis as soon as a mutation is found. Those who accept the offer and are diagnosed as carriers know for certain that they will develop FAP and that regular screening is the only way to escape from an early and deadly cancer. Of those diagnosed as carriers, most if not all will have themselves registered in the national registry at the Foundation for the Detection of Hereditary Tumours. Those who are diagnosed as non-carriers, however, are excluded from risk and thus may abstain from participating in a burdensome and protracted screening program. In other words, DNA-diagnosis made it possible to divide a known population at risk of contracting FAP into a carrier group which can be followed with traditional clinical screening methods, and a non-carrier group which may be excluded from risk and relieved of participation in a screening program. For those who appear to be carriers, DNA-di-

*Figure 3: Introduction of DNA-diagnosis in the field of polyposis (1990s)*



agnosis may have additional value in decisions about prophylactic interventions, and is available in the form of prenatal diagnosis.[2] Thus, options for DNA-diagnosis were readily incorporated in clinical practice as a diagnostic tool which contributes to more efficient and improved forms of preventive care.

## A network of co-existent regimes

In the previous sections we described the emergence of a national screening program in the field of cancer genetics as a process of co-evolution, showing changing configurations of artifacts, practices, professions, users and institutions in which a particular case of "new genetics" has been gradually taking shape. We have described these changing configurations as an extending *network*, that involved new actors – family members potentially at risk, social workers, a national registry, clinical geneticists – and established new alignments between these actors. In this network, the provision of information to family members about the hereditary nature of the disease, the establishment of family trees, the collection of medical data, the offer of DNA-diagnosis and clinical screening became standard elements of the responsibilities of the medical specialist, social worker, or clinical geneticist. The data collected through this network and these efforts, by the Foundation for the Detection of Hereditary Tumours, facilitated not only the organisation of a national screening program, but also the systematic monitoring of its effects and the development of guidelines to be observed in practices of diagnosis and screening. Thus, the extending FAP-network embodied a long-envisaged task to improve the management of polyposis as a hereditary disease.

Our previous account of the emergence of an FAP-network not only describes the mutual shaping or co-evolution in which FAP was transformed from a "fatal disease of the colon" into a "hereditary disorder with preventable consequences". It also shows how this process of co-evolution crystallised into a specific pattern of roles and responsibilities that the actors involved found difficult to deny. In the 1980s, actions and interactions in the evolving FAP-network both shaped and were shaped by what we might call a new *regime of prevention*.[3] In the early 1980s, as the publications in the *Dutch Journal of Medicine* show, medical specialists were already expected to inform FAP patients about the hereditary nature of the disease and the consequent implications for family members. The responsibility of the physician no longer stopped with the treatment of a patient, but also extended to the patient's family. Relatives had to be informed about potential risks and if necessary, according to the ruling standards of the time, considered for regular screening. With the establishment of a national registry, the responsibility of individual specialists to offer information and care to the family of patients became institutionalised on a more collective level in the working practices, database and protocols of the Foundation for the Detection of Hereditary Tumours. In other words, through the efforts of the Foundation, practices of early detection and prevention no longer depended primarily on local initiatives, but had become part of a larger cancer genetic regime of prevention.

When, in the early 1990s, researchers in Leiden found genetic markers on both sides of the so-called APC gene, it became possible to identify gene carriers in families at risk through linkage studies (no direct mutation analysis was possible yet). However, the provision of a DNA-test did not come within the province of the gastro-enterologist or the Foundation for the Detection of Hereditary Tumours. It was the Leiden Centre for Clinical Genetics that organised and facilitated the introduction of DNA-diagnosis in FAP families. As we have already noted in the introduction, centres for clinical genetics in the Netherlands have a privileged position in offering genetic counselling and genetic testing, and in these centres, genetic diagnosis is offered through a practice of counselling in which the autonomous decision making of patients and individuals at risk is the guiding principle. When providing information, counsellors consider it as their task to be neutral and non-directive.[4] The responsibility for decisions and actions to be taken is delegated primarily to the individual asking for information and advice. In the practice of genetic counselling, the principle of informed decision making is also upheld by the relatively long time available for each consult, the obligatory time-frames between consults when clients have to make important decisions, and the extensive documentation of consultations that counselors provide to their clients.

In other words, when DNA-diagnosis became available for those at risk of contracting FAP, it was embedded in a practice of clinical genetics that already constituted a regime of its own. In this regime, *self-determination* was the guiding principle that defined the roles and responsibilities of the actors involved (Nelis 1998 and 1999). In this context, it is interesting to see how medical specialists, in the early 1990s, considered the prospects of DNA-diagnosis in the field of cancer genetics. They referred, first of all, to the promise of improved forms of preventive care, but also pointed out that genetic counselling would deserve particular attention because those at risk of contracting (rare) hereditary tumours would have to face more complex choices (Vasen and Müller 1991). This comment, no doubt, strongly reflected the history and position of clinical genetics as a practice in which DNA-diagnosis was made available to patients and individuals at risk primarily as an opportunity of (informed) choice. In other words, in our account of the emerging FAP-network, the introduction of options for DNA-diagnosis not only involved the extension of this network with a few new elements, but also created a situation of co-existence in this network of two different regimes. Indeed, from the 1990s onwards, FAP patients and individuals at risk found themselves being addressed in different ways: as subjects who need preventive care and as subjects who have to deal with (new) opportunities of choice.

## Ethical norms: External standards or constitutive elements?

From the perspective of more traditional medical ethics, one might argue that our description of a regime of prevention reveals a paternalistic approach towards the choices of individuals at risk, while in a regime of self-determination, professionals rightfully comply to the principles of autonomy and informed consent as defined both by ethical and legal standards.[5] The medical ethics perspective differs in a number of ways from the perspective that we try to develop in this chapter. Most importantly, within the tradition of medical ethics, norms such as patient's rights to free choice and autonomous decision making are defined as external to medical practices, that is, as universal standards which are supposed to guide and direct the daily activities of medical professionals. In contrast to this view, we want to argue that medical standards, rather than being external and given, are constitutive elements being co-produced within medical practices.

As empirically oriented philosophers and STS-scholars have argued, patient autonomy, conceived as a universal normative ideal or ethical standard, may be difficult to localise in current everyday practices of medical care.[6] For example, in an empirical study of decision making practices in a hospital setting, Schermer concludes that decision making in daily care-settings is an ongoing and diffuse process. Decisions are rarely made at one time, in one location or by one person, let alone by "the" individual patient. On the contrary, "there were many moments, with many smaller and bigger decisions clustering together" that jointly produced a particular trajectory or action (Schermer 2001, 9). What we see then is a variety of incidental decisions which are not so much geared towards the question "what does this patient want?" but to the question "what is best for this patient?". According to Schemer, that does not necessarily imply that there is a lack of respect for the autonomy of patients in hospital practices. Rather, one could say there are different meanings of autonomy that shape the relationship between the patient and the medical professionals.[7] Autonomy has "different faces".

Schermer's argument may be read as a critical evaluation of everyday medical practices which takes the normative ideal of patient autonomy as a starting-point. However, we may also understand her observations from a different point of view in which norms are not taken as ideals coming prior to the reality of everyday practices, but as being co-produced in the activities, rules, routines and procedures in which such practices take shape. From this perspective, Schermer's argument also applies to our description of different regimes in the FAP-network, showing how particular subject positions – be it the autonomous patient or the patient needing good care – emerge in various medical practices.

### *Well-being versus autonomy*

Schermer's description of the practices and routines of hospital care obviously has much in common with our previous account of the ways in which patients and individuals at risk move through a FAP-network constituting what we have called a regime of prevention. In accordance with Schermer's observation that "it seemed as if considerations concerning a patient's well-being were far more important than considerations concerning patient autonomy" (82), we find in this regime of prevention a strong focus on the well-being of individuals and families at risk. Indeed, the primary aim of the Foundation for the Detection of Hereditary Tumours is to guarantee optimal care, and so it does everything in its power to encourage individuals to co-operate. In this context, the notion of choice only appears as a valuable opportunity or as a boundary that one should respect. As one of the social workers of the Foundation explains[8]:

> Because of privacy regulations we are not allowed to approach members of the family without their personal consent. Thus, patients are invited by the Foundation to inform relatives at risk. Personal contact with patients at home makes it easier to persuade them that it is necessary to inform other members of the family and also to convince them of the benefit of screening. Sometimes, when patients are reluctant, the family doctor is called in. If members of the family don't want to be informed, then there is nothing more to be done.

Although professionals within the regime of prevention thus occasionally refer to the notion of individual choice as a valuable and indispensable opportunity, the organisation of screening and medical decision making in the FAP-network is governed by judgements, routines and standards in which the medical well-being of patients is clearly assigned priority over other considerations.

This is not to say, however, that individual autonomy only exists as a normative ideal to be confronted with the reality of day-to-day medical practices. Individual autonomy as a standard may also become part of everyday reality, as in the regime of self-determination constituted by the history and practice of clinical genetics. In this practice too, the roles and responsibilities that are ascribed to patients and individuals at risk are shaped by routines and standards indicating the best course of action in the process of medical decision making. Thus, when an individual at risk of contracting polyposis consults a genetic centre for DNA-diagnosis, the counsellor will meet this person on the basis of a specific protocol. In the words of a counsellor:

> According to the protocol, applicants for a pre-symptomatic test first see a clinical geneticist and a psychologist. The clinical geneticist discusses the history of the disease and the personal reasons for a pre-symptomatic test. Then there is a meeting with one of the psychologists who discusses the implications of pre-symptomatic testing. This is followed by a four-week period to think the matter over, after which the applicant returns for a final discussion and decision about the test.

Although the subject positions created for FAP patients and individuals at risk are clearly different in the two regimes we have described, we may conclude that in both regimes these positions can be understood as the emergent result of standards, routines and protocols shaping, and being shaped by, the everyday practices of medical decision making.

### *Standard patients*

In her study of decision making practices, Schermer also observes that when the preferences of patients are taken into account, medical professionals often refer to what they presume patients in general deem as important, that is, to the image of the average or "standard" patient. This observation likewise applies to the efforts of those involved in the FAP-network. As medical specialists have been increasingly convinced of the necessity to regularly screen members of families at risk of contracting FAP, they have created new courses of action for patients and their relatives, and thus also new opportunities of choice. However, in adhering to the rules and standards of a regime of prevention, medical specialists are not seeking more room for choice, but are seeking opportunities to improve care. The course of action indicated is defined by the image of a standard patient who wants to know about his or her risks. Indeed, diagnosis and treatment of and screening for FAP are seen as matters of life (longer) or death (early), and decisions about preventive measures are primarily perceived as medical issues from this perspective (Menko et al. 1999[a], 1999[b]). Such decisions thus will be generally discussed and presented in terms of necessary interventions about which there is little scope for choice. Reflecting on his discussions with FAP patients in the consultation room, a gastroenterologist comments:

> The days that the doctor knew best are long gone. Choices and risks related to the timing and nature of surgical interventions all have to be clearly discussed with the patient. There are a lot of things that have to be considered, including of course the wishes of the patient. . . . Of course, when a colon is full of polyps, it is our task to deliver the message, to say what must be done, and that is, you know, what always will be done.

Of course, not everybody conforms to the image of the standard patient. Sometimes a patient is not prepared to inform other members of the family. And not everyone at risk really wants to be informed. In living their lives and their disease, people thus may choose to follow different trajectories. However, with the emergence of a practice of clinical screening and its development into a cancer genetic regime, some trajectories have been made more comfortable and predictable than others. In the early 1980s, it required a great deal of effort for a medical specialist to maintain a program of screening that would allow every individual at risk to be informed and undergo regular examination. Today, a national registry, social workers who visit patients at home, information leaflets, a system of reminders, working groups, survival rates, guidelines form the constitutive elements of a regime of prevention, offering patients and relatives at risk a course of action that is difficult for them to refuse.

In the regime of self-determination, we indeed find another image of the standard patient as someone who has a great stake in self-determination and non-interference. Thus, in the day-to-day practice of clinical genetics, everything is done to uphold non-directiveness and informed freedom of choice. But, as we have noted above, the presumptions made about the values and preferences of the standard patient need not always match the wishes or views of the individuals involved. For example, in moving through the FAP-network, many patients or individuals at risk experience the genetic centre as "just a stop on their way to the surgeon" (Dudok de Wit 1997, 179). They experience their choice as a purely medical decision and sometimes feel annoyed by appointments with a clinical geneticist or psychologist taking time to explain the implications of predictive testing.[9] As Schermer already noted, autonomy may have many different faces indeed!

### Conclusion: Where do the choices lie?

In our description of the emergent FAP-network in terms of two co-existing regimes, we have focussed on a particular contrast in the ways in which roles and responsibilities are assigned to patients or individuals at risk. In a regime of prevention, individuals are presumed to act as obedient clients with an interest in strategies to prevent future disease, whereas in a regime of self-determination, their role is one of autonomous decision makers, capable of articulating their own will and making use of their right to freedom of choice. In discussing these different subject positions we did not start from a particular notion of the human subject. We have described these positions as constituted in particular practices, that is, as being shaped by a variety of standards, routines, guidelines, forms and services. Thus, in our account, individual autonomy is not taken as a normative and political ideal to be contrasted with the realities of everyday practice. We see the act of self-determination as one of the possible, collective outcomes or effects of the association of a socio-technical network. In the words of Annemarie Mol, we are talking about ontological politics, in which "the crucial moments are not those where 'patients' act as agents, but rather those where they are defined, measured, observed, listened to, or otherwise enacted" (Mol 1999, 87).

Our perspective marks a significant distance from a normative position that starts from a conception of the human subject as a rational, liable and accountable being, thus presupposing freedom of choice is a fundamental condition of existence. From this position, autonomous decision making serves as a universal normative ideal, and the question as to whether individuals have been able to realise their autonomy is considered the major issue in any normative discussion. In our analysis, however, we have tried to move away from dualistic accounts in which autonomy is opposed to paternalism, non-directivity opposed to directivity, and free choice opposed to forms of pressure. We are interested in the questions of where, when and how choices and autonomy appear as part of a story in which the "good" may have many different faces and need not be necessarily related to autonomous decision making (Mol 1997). Thus, in the consultation room of the gastro-enterologist, choices may appear as a valuable option when discussing the operation date with a young FAP patient who first wants to finish school and find a job. But in another situation – when a colon is full of polyps – the doctor, in the words of a gastro-enterologist, simply will have to specify what must be done. In the genetic centre, choices indeed are the trademark of a clinical geneticist. Nevertheless, when the consequences are very straightforward, as with FAP, and somebody does not want to talk and just goes for a blood test, one need not, in the words of a counsellor, always adopt a "holier-than-thou" attitude (interview data, see footnote 8).

Seen from this perspective, the question is not how to evaluate the different practices and regimes in an FAP-network in terms of freedom of choice as a universal normative point of view. Rather, we suggest that in order to understand and evaluate the normative implications of medical practices, we need first of all to understand what "choice" requires and implies in various contexts and thus to study the various ways in which choice may, or may not, become an issue in a variety of local and specific situations.

## Notes

1 We would like to thank Brenda Diergaarde and Annemarie Mol for their contribution to the research that was performed in order to write this article.
2 In practice, however, the option of prenatal diagnosis appears to be rarely used (Whitelaw et al. 1996).
3 According to Rip and Kemp (1998, 338) a technological regime may be defined as "the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artifacts and persons, ways of defining problems – all of them embedded in institutions and infrastructure".
4 This does not imply that other medical practices are naturally directive. What we argue here is the particular emphasis on patient autonomy in the definition and practice of clinical genetics. Whether a non-directive approach is actually possible is another matter. For a critical review of non-directiveness and neutrality, see Van Zuuren (1996, 1997), Steendam (1996), Michie et al. (1997).
5 Paternalism we take here as an act that is performed independent of the wishes of another but with the intention to act to the benefit of that other (Ten Have et al. 1998).
6 See, for example, Berg and Mol (2001), Mesman (2002), Schermer (2001), The (1997).
7 For example, Schermer (2001) argues that as patients often leave the decision making in the hands of what they consider competent professionals, these professionals will experience a moral duty not to harm the trust placed in them.

8 The quotations in this section are taken from interviews with a social worker from the Foundation for the Detection of Hereditary Tumours, a clinical geneticist from the Centre of Clinical Genetics in Leiden, and a gastroenterologist from the University Hospital in Nijmegen.

9 Also, the opposite experience of patients has been noted. For example, in his study of a practice of genetic counselling, Charles Bosk observes that when parents had to make a choice, they often felt left alone by the genetic counselor who in their eyes refrained from taking the responsibility of making the decision with them (Bosk 1992).

# Artifacts and Attachment: A Post-Script Philosophy of Mediation

*Peter-Paul Verbeek*

## Introduction

What should one think of things? This question is a pressing one, now that Technology Studies has discovered artifacts as the objects of inquiry *par excellence.* Societies are not only held together by social relations and institutions, as sociologists and anthropologists claim, but by things as well. Technology should be analysed not only in terms of the social processes in which it is constructed, but also in terms of the role it plays in social processes itself.

Within Technology Studies, the predominant vocabulary for understanding the role of artifacts in society is offered by actor-network theory. Bruno Latour, one of its major representatives,[1] maintains that the social sciences' exclusive focus on humans should be abandoned. The so-called "principle of symmetry" is the most notable feature of Latour's approach, entailing that humans and nonhuman entities should be studied symmetrically. No a priori distinctions should be made between them if we are to understand what is actually happening in society. Not only humans, but also "nonhumans", or conjunctions of humans and nonhumans, should be understood as actors.

An important concept of actor-network theory for analysing these "thingly actions" is "script" (Akrich 1992). This concept indicates that things-in-use can "prescribe" specific forms of action, much like the script of a theatre play, which orchestrates what happens on stage. A plastic coffee cup, for instance, has the script "throw me away after use"; the cameras along many roads in the Netherlands have the script "don't drive faster than 50 km/h". Artifacts are not passive and inert entities. They actively co-shape what actors do.

The actor-network vocabulary for understanding this active role of artifacts in society has proven to be very fertile. Yet, it could benefit from several additions. This becomes clear when it is translated into the context of industrial design. Within that discipline, a discussion is currently waging on eco-design, which aims at finding criteria for designing sustainable products. In this discussion, the Dutch industrial designers association "Eternally Yours" takes an unorthodox stance.

In contrast to the common strategy of trying to reduce pollution in the production, consumption, and waste stages of a product's life cycle, Eternally Yours is looking for ways to enhance product longevity. The primary environmental problem concerning consumer products is, Eternally Yours maintains, that most products are thrown away long before they are actually worn out. Designing clean products does not sufficiently address this problem. Products that are truly environmentally friendly should also create some kind of attachment between their users and themselves, so that they can be cherished throughout their lifespan instead of being thrown away prematurely.

Attempts to enhance the attachment between people and products require an understanding of this attachment, especially with regard to the way in which products themselves can stimulate its generation. The work of Eternally Yours thus raises the question of how the relationships between humans and artifacts can be understood. It will appear that Latour's vocabulary is helpful in answering this question, but that it needs to be augmented in order to do full justice to the role of things in people's everyday lives. I shall develop this augmentation by reinterpreting phenomenology, and by elaborating it literally into a post-script philosophy of technical mediation.

## Eternally Yours

The major aim of the Dutch industrial-designer association "Eternally Yours" is to develop innovative ideas for "sustainable design" (Van Hinte 1997).[2] It considers the current dominant approach within eco-design – which focusses on life cycle analysis (LCA) – too superficial to be genuinely effective. Life cycle analyses anticipate the pollution caused by products in the different stages of their life cycles: production, consumption, and waste. LCA may make it possible to design products that are friendlier to the environment, but according to Eternally Yours, it overlooks the most fundamental problem: the short lifespan of consumer goods. In our throwaway culture, many products are discarded while they remain entirely capable of carrying out their function. Making products less polluting, therefore, is not enough. Environmental pressure will remain unabatedly high as long as all those "clean" products keep being thrown away and replaced as rapidly as is currently the case.

Eternally Yours' worries are not restricted to obvious throwaway products like disposable teaspoons and cups. Research for the Dutch Ministry of Environmental Affairs has shown that a large proportion of our everyday user objects, like hi-fi equipment, stoves, razors, and computers, is discarded although the objects still function well (Eternally Yours 1997, 4). Even worse, some products do not even reach the market. Brand new harddisks are destroyed regularly by recycling companies because they have already become outdated before they were even sold.

The environmental crisis, according to Eternally Yours, is not only a technological problem, but a cultural one as well. The interesting thing about Eternally Yours is that it does not try to evoke the cultural change it considers necessary by creating awareness, but by rearranging *material* culture. It looks for ways to stimulate longevity. Eternally Yours discerns three dimensions in the lifespan of products: a technical, an economical, and a psychological dimension. Products can turn into waste because they are simply broken and can no longer be repaired, because they are replaced by newer models, or because they no longer fit people's preferences and tastes. Of these, Eternally Yours regards the psychological lifespan as the most important (Muis et al. 1997). Many products are discarded because their psychological time is up. In order to create longevity, therefore, Eternally Yours seeks to design things that invite people to use and cherish them as long as possible. "It's time for a new generation of products that can age slowly and in a dignified way, become our partners in life and support our memories," as the Italian designer Ezio Manzini put it on Eternally Yours' letter head.

The crucial question for sustainable design is therefore: how can the psychological lifespan of products be prolonged? How can things stimulate the forging of a bond between their users and themselves? In three subprograms, Eternally Yours develops ideas to find answers to this question. In the program "Shape 'n Surface", it searches for forms and materials that could create longevity. Materials are being tested that do not become less attractive through aging but have "quality of wear". Leather, for instance, is generally found more beautiful when it has been used for some time, whereas a shiny polished chrome surface looks worn out with the first scratch. A good example of a design within this program is the upholstery of a couch that was designed by Sigrid Smits. An initially invisible pattern is stitched into the velvet that is used for it. When the couch has been used for a while, the pattern gradually becomes visible (Muis et al. 1997). Instead of aging in an unattractive way, this couch renews itself as it ages.

The second Eternally Yours subprogram called "Sales 'n Services" pays attention to the ways in which the services around products can influence their lifespan. The availability of repair and upgrading services can prevent people from discarding products prematurely. Companies can shift their core activities from continuously producing and selling new products to maintaining sustainable relations with customers.

The third subprogram, "Signs 'n Scripts", investigates the role of the semiotic and symbolic aspects ("signs") of things in their lifespan, and their implicit prescriptions about how to use them ("scripts"). Stories around products, for instance, can give them more "character", like a Nikon advertisement some time ago, showing a camera that had been lying on the bottom of the ocean for ten years but still worked. This camera is not portrayed as the latest model with the newest features, but as a reliable product the owner can be proud of. The bond between people and products can also be influenced by *scripts*: things can create attachment by demanding that they be dealt with in a certain way. This aspect of products will be elaborated later in this chapter.

To elaborate these programs, Eternally Yours needs a vision of products that goes beyond the standard approaches within industrial design. Products are commonly approached in terms of their functionality on the one hand, and their style and meaning on the other. They are designed to work and, as a semiotic surplus to their functionality, to embody a style that fits their intended owners. In our postmodern consumption society, products should not only work, but also be expressions of lifestyles. For example, Braun manager Godehard Günther says in a textbook for industrial designers: "We do not sell devices, but a way of living". The French suitcase company Louis Vuitton adds: "Of course we produce top solid travel equipment, but we also sell myths and dreams, a certain way of travelling. Luxury, independence, and a feeling of flexibility are what characterise the owner of a Vuitton suitcase" (Bürdek 1996, 228 – my translation).

To Eternally Yours, however, functional and semiotic approaches to things do not suffice. If products were only designed from the perspective of their functions, people's attachment would not concern the products themselves, but only what the products *do* for them. People would not care whether it is this specific product they are dealing with or not. In Albert Borgmann's terms, it would be at best the commodity delivered by a product that would matter, not the product itself, i.e., the machinery that does all the work (Borgmann 1984). Conversely, if things were only present as signs for lifestyles and identities, people could only get attached to these signs, not to the things that carry them. If products are to invite us to get attached to them, therefore, they should not be present to people as mere carriers of functionality and meaning, but also as material entities. The attachment they enable should not only concern their functions or meanings, but the products *themselves*.

Thus from a practical point of view, Eternally Yours stumbled upon the importance of the materiality of things. But how should this materiality be conceptualised? How can one do justice to it when thinking about things – without recurring to a naturalistic or naive realist position which pretends to be able to get in touch with "things themselves"?

### Conceptualising materiality

Latour's theory of technical mediation offers a way to do justice to this materiality of things. I shall limit myself here to the way he developed his position in the articles *Where Are the Missing Masses? – the sociology of a few mundane artifacts* (1992) and *On Technical Mediation* (1994), which re-appeared in a slightly adapted form in *Pandora's Hope* (1999[a]) as "A Collective of Humans and Nonhumans". As pointed out in the introduction, Latour proposes treating people and things ("humans" and "nonhumans") symmetrically. Actions are usually performed by compositions of humans and nonhumans. If I cycle to the university where I work, my travelling is performed jointly by my bicycle and I. There is neither any biking without me, nor without my bicycle. The nonhuman parts of such compositions should not be understood as passive and neutral instruments. They actively co-shape the action that is performed, that is, they co-act. Without a bicycle, my travel would be entirely different, and so would my contact with my surroundings.

Latour's principle of symmetry is of great importance to developing a more material way of thinking about things. Not only does it show that things have a capacity to act, but also that they have this capacity by virtue of their materiality: their concrete "thingly" presence. The way my bicycle mediates my contact with the landscape is not part of its functionality or style. The specific way in which the bicycle, as a physical object, enables me to go to work organises my relation with the environment in a specific way. This "surplus" of what things do besides function can be described as *mediation.*

To Latour, mediation primarily concerns *action.* However, he is no classical actiontheorist. In his approach, "action" does not indicate the conscious activities of intentional subjects, but simply all that is "happening", which, therefore, leaves traces on reality. Mediating action is co-shaping what is happening. Artifacts can play such a mediating role, for instance, by demanding that they be dealt with in a certain way. To mention some of Latour's examples, speed bumps mediate people's driving behaviour by encouraging them to drive slowly. Door springs mediate the speed with which people can enter a building, by giving them only a certain amount of time to enter. Heavy weights attached to hotel keys mediate whether or not people return those keys to the reception desk, because they are usually too cumbersome to carry around for a long time. The mediation of action, according to Latour, has the form of "prescriptions" that can be expressed in language as a "script", a series of instructions on how to act. The speed bump mentioned, for instance, has the script "slow down when you approach me"; a plastic coffee cup says "throw me away after use", as was cited in the introduction. Things mediate action here as material things, not only as carriers of signs or functions. A traffic sign makes people slow down in quite a different way – if it does so at all – and the function of a coffee cup does not include of making people throw it away.

In *On Technical Mediation* Latour develops four concepts to help understand the mediating role of artifacts. He discerns *translation* as the first meaning of "mediation". When artifacts mediate, they translate what Latour calls "programs of action". If someone is angry with somebody else, he or she might have the program of action "take revenge". If the anger is very strong, and there happens to be a gun around, this program of action could be translated into "shoot that person". The program of action is then translated into a new one, and along with this, both the angry person and the gun have changed as the person becomes a potential killer and the gun, a potential murder weapon instead of being just a deterrent object lying about. In this translation, both human and nonhuman aspects play a role. The human intention to express anger and the nonhuman function of the gun to shoot a bullet merge into the hybrid of "a person with a gun", which can only be understood by taking both its human and its nonhuman aspects into account.

This emergence of hybrids can be indicated by the second term from Latour's vocabulary of mediation: *composition*. Mediation consists of enabling the generation of new programs of action on the basis of the newly developing relations between the actants in question. This implies that the new program of action is owned by a "composite actant", and that responsibility for the resulting action should be spread among all actants involved. "Action is simply not a property of humans but of an association of actants" (Latour 1994, 35).

Mediation thus consists of mixing humans and nonhumans. This mixing work usually remains hidden, however. Most of the time it is "black-boxed": the composite actant is taken for granted, making the "joint production of actors and artifacts entirely opaque" (Latour 1994, 36). This *reversible black-boxing* is the third meaning of "mediation". To return to a previous example, all the work that has been done to design and produce a bicycle remains concealed. But when the chain runs from the sprocket, suddenly all kinds of entities "materialise" around the bike, as Latour would phrase it: a sprocket and a chain, which were not explicitly observed when biking, a repair person, the tools needed to repair the bike. All these entities are required to make the bike work as they are mixed together into the hybrid we call a bicycle. They therefore mediate my relation with my bike, and make it possible for me to have a bicycle that mediates my going to work, and especially, the *way in which* "I" do that.

The fourth and last term in Latour's vocabulary of mediation is *delegation*. Latour calls this the "most important meaning of mediation" (Latour 1994, 38). The concept of delegation indicates that programs of action can be "inscribed" into artifacts. The speed bump is a good example of this, according to Latour. If local authorities want people to drive slower in certain areas, they can do several things. They can put traffic signs along the road with an indication of the maximum speed allowed, put a policeman near the signs, or install a piece of concrete that is charged with the task of ensuring that people do not drive too fast. The program of action "make drivers slow down" is thus inscribed into a piece of concrete, which now becomes a "speed bump" with the script "drive slowly or damage your shock absorbers". Such delegations, according to Latour, enable a remarkable combination of presence and absence. The past action of an absent actor – the designer of the speed bump, or the mayor who insisted that the bump be placed – exerts influence on people's behaviour here and now.

These four aspects of mediation are closely connected. With regard to the speed bump, the authorities allied themselves to a piece of concrete (composition) and conveyed all that is needed for the realisation of their goal to the speed bump (delegation); after this, the bump can handle things by itself (black-boxing), because it changes the program of action of drivers from "driving slowly because of responsibility" into "driving slowly in order to save my shock absorbers" (translation). Translation, composition, reversible black-boxing, and delegation each form an aspect of technical mediation that could not exist without the others.

### Delegation and symmetry

Latour's approach to things can be helpful to the Eternally Yours program. He shows that products have "scripts": they mediate action. Artifacts influence the way in which people do things, and this influence could be deliberately inscribed into them. To Eternally Yours, the most interesting scripts are those that evoke attachment between products and user which therefore stimulates people to throw away products less quickly. Sustainable products should invite people to develop a durable relationship with them. When trying to imagine what inscriptions that promote this kind of attachment might look like, however, it becomes clear that Latour's theory of mediation could benefit from some refinement and addition.

People can only develop a durable relationship with artifacts if what matters is not just a matter of style or function. After all, other artifacts could embody the same meaningfulness or functionality, but no other artifact can be this specific material thing, here and now. If someone is only attached to the *style* of a product, this product could as well be replaced by another one with the same sign value or the same iconography for the lifestyle this person wishes to be associated with. If it is only the *function* of a product that matters, then it could just as easily be replaced by an artifact functioning equally well or even better. In order to create attachment between people and products, products should be present and applicable in terms of their *materiality*, and not only their functionality or meaningfulness.

In order to be present to people in a material way, products could be designed to engage users explicitly in their function – including their durability, repair, and upgrading. If people need to interact with a product, their attention is not only directed at what it accomplishes or expresses, but also at the product itself. Many of Eternally Yours' solutions actually work this way: they engage people with their materiality. The stitched velvet mentioned above involves people in the wearing process. Upgradable and repairable products make people part of their aging and maintenance processes.

When trying to conceptualise how such "engaging products" can be present for people, however, it appears that it is not so much delegations from humans to things that are relevant here, but delegations *from things to humans*. If people are to be involved in the functioning of products, these products should delegate specific tasks and responsibilities to people. Delegations of this kind are underexposed in Latour's analysis of technical mediation. In his examples, Latour focusses on delegations from humans to nonhumans. The speed bump, key weight, and door-spring aforementioned do what they do because people told them so; in other words, officials have bumps installed because they want people to drive slowly; housekeepers install door-springs to prevent draughts; hotel owners attach weights to their keys to stimulate guests to return them to reception when leaving the hotel.

This one-sided focus raises the suspicion of asymmetry. This suspicion is reinforced by Latour's use of the concept of "inscription". Scripts are supposed to be the products of "inscribing", i.e., they are reducible to human activities. The same line of thought can be found with Akrich, when she first introduced the "script" concept: "Designers thus define actors with specific tastes, competencies, motives, aspirations, political prejudices, and the rest (…) A large part of the work of innovators is that of *'inscribing'* this vision of (…) the world in the technical content of the new object. I will call the end product of this work a 'script' or a 'scenario'" (1992, 208; her emphasis). Both Latour and Akrich see scripts as the result of "inscriptions" – and inscription is an asymmetrical concept, since only humans have the ability to inscribe.

There is no real asymmetry involved here, however. Implicitly, Latour *does* discuss delegations vice versa: from nonhumans to humans. In *Where Are the Missing Masses?*, for instance, he expresses his admiration for a hydraulic door closer, because it easily absorbs the energy of those who open the door, retains it, and then gives it back slowly "with a subtle type of implacable firmness that one could expect from a well-trained butler" (Latour 1992, 233). This door-closer delegates to people the delivery of the energy it needs to close the door after it has been opened. Openness to delegation of this kind is crucial because, otherwise, only those forms of mediation that are explicitly intended by humans can be perceived, whereas things often do more than that. A revolving door has been delegated the task of keeping out draughts, while still maintaining the possibility of entering a building. That it also keeps out people in a wheelchair was nobody's explicit intention. Nor did the designers of the hydraulic door-closer intend them to discriminate against children and elderly people who are not strong enough to open them (Latour 1992, 234).

Yet, Latour's focus on delegation and inscription remains remarkable. If we are to understand the ways in which artifacts mediate, it does not matter all that much how they came to do so. What is important is *that* they play mediating roles, and the most relevant question to an analysis of technical mediation is *how* they do this. Focussing on the generation of the mediating roles of things could be seen as a relic from the early days in STS, when the ambition was to show that "facts" or "technologies" are actually contingent outcomes of processes of construction in which many actants interact. This deconstructionist approach aimed to unravel how entities come to be what they are. An analysis of the mediating role of artifacts can take the constructedness of this role for granted, however. For the understanding of technical mediation, the inscription processes and delegations from humans to nonhumans may remain black-boxed. Only the mediating role itself is relevant here, not its origins.

In their research into drug users and amateur musicians, Emilie Gomart and Antoine Hennion also observe the limitations of understanding mediation in terms of "inscriptions" and "delegations". In their view, concepts like these "render" objects "as prolongations of actions already initiated elsewhere; moreover, these object-mediators do not just repeat and relay actions but also transform these in surprising ways" (Gomart and Hennion 1999, 225). Their solution is to replace the concept of "action" with that of "events". The attachment between people and drugs or music cannot be adequately understood in terms of "action": the experiences of drug users and amateur musicians are events which "cannot be reduced to an interaction of causal objects and intentional persons" (Gomart and Hennion 1999, 226). The role of the "things" involved in these events (the drugs and records) should not be understood in terms of what has been delegated to them. Rather, they are "the locus of an event", as Gomart and Hennion phrase it: "There, in that encounter, the user is seized at those very points of asperity (or affordance) that are made possible and relevant by the sophistication of his/her own practices and vocabularies, as well as by the properties of the objects used" (Gomart and Hennion 1999, 243).

Although Eternally Yours needs somewhat different forms of attachment than that of drug users and music amateurs, Gomart and Hennion are right when they say that mediating artifacts should be approached as entities around which events occur, not as the outcomes of processes of interaction. This change of perspective creates the space necessary to see how artifacts actively co-shape the events around them, and to understand these events not only in terms of *action* but in terms of *experiences* as well. Delegations from things to people, not from people to things, form one way in which artifacts mediate what happens around them – a way that is particularly important to Eternally Yours. The attachment between users and industrial products that can come about in this mediation is less intense than that of drug users and amateur musicians. Where the latter are "seized" by the artifacts that mediate their experiences, the former are "engaged" by products that delegate tasks to them. Nonetheless, the structure of both attachments is the same. Just as the experience of drugs and music is always a blend of activity and passivity, striving and being seized – the users of engaging products both actively use the artifact and are used by it.

In order to be really helpful to Eternally Yours, this "expansion" of ANT needs to be carried a bit further. Not only the structure of attachment should be analysed, as was done by Gomart and Hennion, but also the role artifacts play in the realisation of this attachment. An analysis of this role should go beyond the concept of "script" if we are serious about replacing "action" with "events" in our analysis. The "script" concept remains biased toward action: scripts are defined as sets of "prescriptions" on how to act (Latour 1992, 232-233). And, more importantly, it erroneously suggests that mediation is a property of the artifacts themselves, not of the relationship between humans and artifacts. Artifacts are supposed to "have" scripts where the mediating forces that co-shape the events around artifacts are localised in the artifacts themselves. After all, if this were not the case, it would not make sense to speak of delegations "to" nonhumans and inscriptions "in" artifacts.

An alternative interpretation of technical mediation can be developed, however, that does not localise mediation in the mediating artifacts themselves, but in the *relationship* between people and artifacts, or better such as in the "artifactually" mediated relation between humans and their environment. In order to understand the "encounter" between humans and objects – as Gomart and Hennion call it – in a more detailed way than ANT does, a reinterpretation of phenomenology offers a suitable framework. In this reinterpretation, classical phenomenology is freed from the essentialist and romantic connotations that have become connected to it over the past century. Within the resulting "postphenomenological" perspective – to use a term of Don Ihde in a somewhat different way than he does himself[3] – phenomenology is understood as analysing the relationships between humans and their world. Technical mediation should be localised precisely in these relationships.

## A postphenomenology of attachment

### *Postphenomenology and actor-network theory*

During the first half of the 20th century, phenomenology was an influential philosophical movement. However, its influence has steadily waned over the past few decades. Phenomenology aroused the suspicion of being a romantic and essentialist approach. It was increasingly at odds with the rising contextualism in philosophy, brought about by the emphasis on both linguistics and postmodernism. Nevertheless, it is possible to formulate a phenomenological perspective that leaves these problematic connotations behind. This "postphenomenological" perspective appears to complement ANT in several ways.

Like actor-network theory, phenomenology developed in opposition to the realism and positivism of the sciences. Seen from a present-day perspective, however, it ultimately did this in a highly problematic way. Against the claim of the sciences that they would reveal reality as it "truly" is, phenomenologists like Merleau-Ponty stated that scientifically interpreted reality was actually a derivative from a more fundamental one – that of the reality of everyday experience. Only on the basis of experiencing the meaningful, everyday world, Merleau Ponty claimed, can the sciences build their abstractions.[4] In opposition to the sciences, therefore, he saw phenomenology as a method for "describing" the world, not "analysing" it.[5]

Classical phenomenology – at least some positions within it – thus tried to counter the sciences with an alternative claim. Not science but phenomenology itself would be able to get into contact with "reality itself". This "phenomenological realism" has become problematic in the light of the currently dominant view that the relationship between humans and reality is always mediated and contextual. The romantic search for "authentic" access to reality, in order to overcome the alienation brought about by science, ultimately got phenomenology into trouble.

However, phenomenology does not need to be just as a philosophy of alienation. Classical phenomenologists saw it as their ultimate goal to "describe the world" (Merleau-Ponty) or to understand the "intuition of essences" (Husserl) or the "self-manifestation of being" (Heidegger), but in their attempts to reach these goals, they accomplished something else as well. In order to understand these "essences", "world", and "being", they all developed analyses of the *relationships* between humans and reality. Husserl analysed this relationship in terms of consciousness, Merleau-Ponty in terms of perception, Heidegger in terms of being-in-the-world. It would be more modest and less problematic, therefore, to understand phenomenology as *analysing the relationships between humans and their world.*[6] In this way, the pretension to possess the key to authentic contact with reality is relinquished.

Common to all classical phenomenological analyses of human-world relationships is that they contain a variant of Husserl's concept of "intentionality". To Husserl, this concept made it possible to navigate between the cliffs of realism (the idea that the world can be known as it is "in itself") on the one hand, and idealism (the idea that the world we know is a product of our consciousness) on the other. Husserl claimed that subjects and objects cannot be separated in this rigid way, but are instead always interrelated. The concept of "intentionality" indicates that humans are continually directed towards their world. People cannot help but be involved with their world as they are always experiencing it, and it is the only place where they can live their lives. In everyday life, subject and object are never separated, as realism and idealism suggest, but are always already interrelated.

Radically interpreted, this concept of intentionality is able to avoid the pitfalls of romanticism and essentialism mentioned above. Subject and object should not be seen as simply "related to each other"; they *constitute* each other in their interrelation. In their mutual relationship, they co-shape one another. In each situation, humans are what they are on the basis of their relation to their world, and their world is what it is on the basis of their relation to it. In their involvement with reality, humans necessarily disclose it in a specific way, and are themselves constituted in specific ways. In the interrelation of humans and world, therefore, a specific "objectivity" of a world and a specific "subjectivity" of humans are generated. It should be mentioned that none of the two poles may be made absolute here. People cannot arbitrarily disclose any world, since there is always "something" that is disclosed as a world. Conversely, the fact that humans are what they are on the basis of their relation to the world does not imply that they are entirely determined by it.

As later phenomenology did – including the later Husserl himself – this view of phenomenology replaces Husserl's transcendental subject by an existential subject, and does not conceive the world as a collection of "objects", but as a lifeworld. The world is the place where humans realise their existence, and which is continually experienced and interpreted by them. What sets my reinterpretation of phenomenology apart from classical phenomenology, however, is the centrality of the notion of mutual constitution and, as will become clear below, the notion of the mediated character of this constitution. Husserl, too, used the concept of "constitution" in his work, but he localised it exclusively on the subjective side: he tried to understand how subjects constitute a world. As opposed to this, I localise constitution in the interrelation of subjects and objects. Not only objects but subjects are also constituted in the intentionality relationship that exists between them.

The phenomenological perspective I defend here has the same symmetrical intentions as are present in Latour's work in that it tries to overcome the "Grand Canyon" between subject and object by showing that both cannot exist separately. It even goes one step further, by stating that subject and object *constitute* each other. The resulting "postphenomenological" perspective overcomes the dangers of classical phenomenology by working out the classical aversion to context-independent truths and radical subject-object distinction in a new way. It considers the "postmodern" reduction of reality to language games, contexts, or other deconstructionist elements to be inadequate as well, since these only confirm the subject-object distinction by stressing the subjective side. Postphenomenology holds that realities come about in relations, as well as the humans that are related to these realities. Like actor-network theory, phenomenology stresses the contingency of reality, and the need for a "relational ontology" where reality is only given in the relations humans have with it.

The main difference between postphenomenology and actor-network theory is that postphenomenology is primarily interested in the *relationships* between people and the world, instead of the "constructions" that arise in and through them. To ANT, these relationships consist of networks of humans and nonhumans within which reality is constructed; to postphenomenology, they consist of the intentional relationships between humans and their world, in which both "objectivity" and "subjectivity" are constituted.[7] Postphenomenology does not bridge the "Grand Canyon" between subject and object by blurring the distinction between them – as ANT does, claiming that they are to be treated as semiotically equivalent entities – but by showing that they are intertwined, even at the level of their constitution. Postphenomenology aims to understand the "contact" between humans and world: the experiences and actions in which they co-shape each other.

Seen from the perspective of ANT, postphenomenology might appear to be a very limited approach, since it only studies very short networks. After all, the human-world relationships it analyses involve only two actants: a perceiving or acting human and an actant (human or nonhuman), which is experienced or interacted with. At best, three actants are involved: when technical mediation occurs, a third, nonhuman actant is added to the network. When humans are indicated by an "H" and nonhumans by "N"[8], a postphenomenological perspective on mediation only analyses the networks H-NH-NH and H-NH-H. But this simplicity is no shortcoming. The fact is that actor-network theorists could treat each of the three elements of the human-technology-world network as a black box, containing networks of any desired complexity. Postphenomenology does not deconstruct these entities, simply because it asks a different question than ANT does. It is not primarily interested in the networks *behind* entities, but in the relationships humans can have with them – whether they are constructed or not. Postphenomenology studies these relationships in a more detailed way than ANT investigates the networked connections between actants. Where Latour simply speaks of "associations", postphenomenology studies these associations in a differentiated way. Human-world relationships comprise action and experience, and mediating artifacts can be present in several ways in this relationship, as will become clear below.

### *Technological intentionality*

The postphenomenological point of view offers new possibilities for understanding mediation by artifacts. It suggests that mediation takes place in human-world relationships: when artifacts are used, they enable and co-shape relationships between humans and their environment. This implies that artifacts do more than mediate action. Action is only one aspect of the relationship between humans and their world, an aspect that becomes visible when approaching this relationship "from the human side", since action can be seen as the way humans can be present in their world. However, the human-world relationship can be approached from the opposite direction as well. Seen "from the world side", it concerns the ways in which reality can be present for people. This counterpart to "action" is "experience". The contact between humans and the world, therefore, has two modi: action and experience, aggregating into "ways of existing" (existentially) on the one hand, and "forms of interpretation" (hermeneutically) on the other.

The distinction between action and experience allows an expansion of Latour's analysis of technical mediation. When an artifact is used, it co-shapes human-world relations by giving shape not only to people's actions but also to people's experiences. When using a car, for instance, the car mediates the relationship between a person and his or her world. It lets this person be present as a driver, who's able to move quickly from one place to another. This contributes to the generation of specific forms of existence. A car, for instance, allows people to choose a place to live that is far from work, and maintain social relationships outside their immediate living environment. At the same time, it lets the environment through which he or she drives be present in a specific way. From a car, one cannot smell or hear the environment, instead one receives intense and rapidly changing visual impressions. When I take the bicycle to work, my commuting has a completely different character than when I take the car or walk, as does my relation to the meadows, the cows, and the people I pass. A car not only mediates people's actions but their experiences as well. It co-shapes the ways in which humans can be present in their world and the ways in which reality can be present to humans.

This expanded understanding of mediation invites an expansion of the concept of "script" as well. Within Latour's analysis, scripts are primarily related to action. Scripts concern the translation, inscription, and delegation of programs of action, whereas a concept is needed that indicates mediation in the broadest sense, a mediation of the interrelationship between humans and their world. Don Ihde's concept of "technological intentionality" could serve this purpose, in a slightly adapted way.

With "technological intentionality", Ihde indicates that technologies have "intentions" – they actively shape people's relations with their world.[9] A pen, for instance, asks for a completely different writing style than a typewriter and a word processor do. With a pen, people tend to write longer, carefully formulated sentences, whereas a typewriter invites a more speech-like style of writing (Ihde 1990, 141-143). As Latour does with "scripts", Ihde implicitly localises this technological intentionality in the things themselves. From a post-phenomenological perspective, however, it is more adequate to localise technological intentionality in the relationship between humans and their world. Within classical phenomenology, this relationship has been called "intentionality", as the above section showed. What Ihde in fact brings to light is that technologies can create a "technologically mediated" intentionality, a relationship between humans and a world in which their mutual constitution is mediated by technological artifacts. When technologies are used, they co-shape human-world relationships: they make possible practices and experiences, and in so doing, they play an active role in the way humans can be present in their world and vice versa. I would like to define "technological intentionality", therefore, as an abbreviation of "technologically mediated intentionality".

This definition of technological intentionality implies that the mediating capacity of artifacts is no essential property of things themselves, but emerges from the interplay of things and their context. Technologies are "multistable", as Ihde observes, in that they are what they are only within the context in which they are used (Ihde 1990, 144-151). What things are, and therefore how they mediate the mutual constitution of people and the world, emerges from people's relationships with them. Mediating things have to be constituted themselves before they can mediate the mutual constitution of people and the world, to phrase it in the vocabulary of classical phenomenology. A revolving door can constitute a building as inaccessible for persons in a wheelchair, and as draught-free for people who are able to enter it. In the first case, it constitutes its user as disabled, in the latter as mobile enough to pass through. The mediating role of the door depends on the kind of relationship someone has with it. Its "stability", and therefore its mediating role, "emerges" from the interplay between the door and its users.

Since technological intentionalities, unlike scripts, are not properties of artifacts themselves, but technologically mediated relationships *via* artifacts, it is not possible here to reduce artifacts to what was delegated to them by people. Nobody delegated to a revolving door that it should prevent people in wheelchairs from entering the building. Within a postphenomenological perspective, the reduction of nonhumans to humans or the other way round is simply not an option. Humans and the world are distinct and irreducible to each other, but they are nevertheless also inextricably intertwined and co-shape each other. Postphenomenology, in other words, does not abolish the distinction between humans and nonhumans, but shows their fundamental connectedness and interrelatedness. Artifacts mediate ways of existence (subjectivities) and experienced realities (objectivities) not because people told them to do so, but because of the relation between humans and the world that comes about *through* them.

*Engaging mediators*

The postphenomenological perspective on mediation allows for an approach to artifacts in which their mediating role is not reduced to what humans delegate to them. Localising the mediating role of artifacts in the interplay between humans and the world grants things the degree of independence they deserve. Although they do not autonomously shape human-world relations, their role cannot be entirely reduced to "non-thingly" factors.

The postphenomenological perspective on mediation, therefore, does justice to the materiality of things, and this might make it useful to Eternally Yours. What Eternally Yours needs, after all, is an approach to things that, in contrast to the predominant focus on functionality and meaningfulness within industrial design, focusses on the relationships between people and things themselves.

Earlier in this chapter, it became clear that in order to be "eternally ours", things should evoke engagement with themselves as material entities. To accomplish this, it was said, products could be designed in such a way that they engage people in their functioning. A postphenomenological perspective on human-artifact relationships can shed more light on this engagement, and therefore it might be helpful when looking for ways to stimulate it. In order to understand situations in which things involve people in their functioning – situations that in a Latourian vocabulary could be called "delegations from nonhumans to humans" – another (but short) expansion of the theory of technical mediation has to be made. In order to understand engagement with products, it is not only necessary to understand how artifacts mediate human-world relationships, but also *how they are present* for people when they do so.

Things mediate human-world relationships when they are *used*, and things-in-use are present in a peculiar way: they are present and absent simultaneously. When a technology is used, people's attention is not directed at the technology itself, but at what they can do or experience by means of it. If this were different, after all, it would not be possible to *use* things. Technologies only draw attention to themselves when they break down. When hammering a nail into the wall, people's attention is not directed at the hammer, but at the nail; only when the head comes loose from the handle does the hammer ask for attention. Heidegger called these two modes of human-artifact relations "readiness-to-hand" (*zuhandenheit* – artifacts-in-use) and "presence-at-hand" (*vorhandenheit* – artifacts asking attention for themselves).[10]

The distinction between being "ready to hand" and "present at hand" can be a starting point for understanding the relationship between humans and "engaging objects". The fact is that engaging objects merge these two modes of thingly presence in a specific way. From the perspective of Heidegger's distinction, the concept of "engaging technologies" might seem paradoxical at first sight. After all, how can a technology withdraw and at the same time ask for involvement and engagement with itself? From what has been stated above, it seems to follow that technologies that ask for involvement with themselves cannot be used at all because people's attention can only be directed at the object itself, not at what could be done by means of it. But, engaging technologies do exist. Artifacts that can ask for involvement do not necessarily have to be entirely present-at-hand.

Compare, for instance, a piano with a CD player. A CD player in use is ready-to-hand in that it withdraws from people's attention and becomes transparent in order to give access to the music it plays. A broken CD player is present-at-hand in that it is not transparent but opaque, because it blocks people's access to the music it could play if it worked. The way in which a piano is present combines these two modi of presence. It is ready-to-hand, but still engages people in its functioning. If it were not ready-to-hand, it could not give access to the music that can be played on it. Only when someone is learning to play is the piano present-at-hand, and the piano player's attention is only directed toward the piano itself. After this learning stage, the piano player becomes engaged with the music he or she plays on the piano. The piano never completely withdraws, however. In order to be played, it asks for a lot of involvement as a physical entity. Whereas a CD player only asks you to press a button, a piano demands an intense bodily engagement of the player.

An important dimension of this "engaging capacity" of artifacts is the *skill* that is needed to interact with them. Skill can be seen as the effort needed to "appropriate" artifacts. What sets a piano apart from a CD player is the degree of skill that is required to use it. To use a CD player, one only has to know how to turn it on and off. Once the CD is playing, no skill is required to listen to the music. This degree of engagement does not require skill. The most important aspect of engagement with artifacts – which is also central in acquiring skill – is the necessity to interact with its machinery. The engagement a piano evokes is not comparable to the interaction with, for instance, a hammer. A hammer does not require active engagement with its machinery. For someone who has learned to use and "incorporate" a hammer, it becomes an extension of the body. A piano, by contrast, never becomes an extension of the body, even for the best piano players. It requires active and concentrated interaction with its keys and pedals, and therefore it never withdraws from a player's intentionality relationship with his or her world.

The possibility of an "engaging presence of things" can be of importance for Eternally Yours.[11] Artifacts can invite relations with themselves, making possible engaging practices in which they partly withdraw from people's attention, but yet still involve users in their functioning. In such cases, artifacts mediate people's relationship not only with their world, but also with the artifacts themselves. This type of mediation can provoke attachment to the materiality of things – the kind of attachment that would be helpful for Eternally Yours.

Such engaged ways of interacting with objects also play an important role in Gomart and Hennion's aforementioned research on "attachment". A post-phenomenological perspective could enrich the vocabulary for analyses like theirs, since it offers concepts for understanding the way artifacts are present in events of attachment. Artifacts are the "locus" of such events, as Gomart and Hennion say, but this locus is by no means static and passive. Attachment comes about when artifacts invite engagement with themselves, and at the same time create scope for people to experience and interact with the world around them. They are somewhere in between "presence-at-hand", by asking for engagement, and "readiness-to-hand", by allowing humans to *do* something with them instead of only interacting with the artifacts themselves.

However, looking at products in terms of their "engaging capacity" is far from obvious. Most technological products avoid provoking engagement. This is quite understandable, since people usually do not use technologies in order to be engaged, but to be disburdened. As the philosopher of technology Albert Borgmann shows, technologies tend to put their machinery in the background in order to allow people to enjoy the commodities they procure as quickly, easily, safely and ubiquitously as possible (Borgmann 1984, 41). Technologies do things *for* us, instead of asking things *from* us. We prefer a water tap to a well, because a tap does not require us to take a walk, lower a bucket, haul it up again, and walk back home. A tap only asks for a simple, hardly noticeable action in order to obtain water. This is the typical pattern of technology – it creates the availability of commodities by diminishing the need for involvement in their materialisation.

From this perspective, the challenge for culturally sustainable design is to break this consumptive pattern in a playful way. In order to evoke attachment, things should ask for engagement instead of the mere consumption of their commodities. An attractive example of such engaging products is the award-winning "electric/ceramic heater", designed by Sven Adolph at Cranbrook Academy of the Arts (Chicago). It consists of a heating element surrounded by several concentric, cylindrically shaped ceramic shells of various heights, each with a vertical aperture. The shells can be arranged in several ways, so that they radiate their warmth in different directions. This artifact is not a purely functional heater that withdraws into pure functionality, like common radiators, which are usually hidden under the windowsill and only ask to be turned on and off. Adolph's shell heater is an engaging product that asks for attention and involvement in its functioning. It is intended to be placed in the middle of the room as if it were a campfire. You cannot escape it if you need warmth, because you have to sit around it. Its shells have to be arranged in a certain way if we want it to function. Simply turning the heater on and off is not enough; you actually have to get involved in its functioning if you want it to work.

Another interesting example of engaging products is Donald Carr's "Ithaca Color Printer", also designed at Cranbrook Academy. It is a colours inkjet printer with entirely transparent machinery. It possesses four reservoirs, for black, yellow, red, and blue ink, and the printer head remains visible when it is functioning. The open architecture of this printer not only makes it fascinating to *watch* the printing process – which would not be enough to evoke durable attachment – it also makes the functioning of the printer understandable, and it is therefore able to *involve* humans in its functioning. It can be refilled with ink when needed, and if mechanical problems occur, they can easily be fixed.

When handling Adolph's heater and Carr's printer, users are confronted with the materiality of these products. They are not present simply as providers of warmth or printed text. Users are playfully forced to participate in the processes that make these commodities available and in which the machinery of products plays a central role. Engaging products do not make themselves invisible. They maintain present in people's attention during use , without being present in the foreground of our experience.

## Conclusion

The ambition of the Dutch industrial-designer association Eternally Yours to find ways of designing "culturally sustainable" products shows several opportunities for expanding Latour's theory of technical mediation. First, Eternally Yours makes visible the need to expand the concept of delegation, so that it covers delegations from nonhumans to humans as well. These nonhuman delegations could play an important role in the attachment between humans and things. For this attachment to come about, products could delegate the responsibility for parts of their functioning from their machinery to their users. In this way, users are engaged with the materiality of products, not only with their functionality or meaningfulness – which are the predominant foci in current industrial design.

Second, it became clear that the concept of "script" should be expanded to "technological intentionality", in order to be able to localise the "mediating capacity" not in the artifacts themselves, but in the relationship between humans and their environment that is enabled and mediated by these artifacts. "Scripts" or "technological intentionalities" should not be seen as properties of artifacts, but as features of configurations of humans and things, in which some actions are stimulated and others prohibited.

Third, it has become clear that "mediation" concerns not only action but experience as well.

The contours of a postphenomenological perspective on technical mediation have been sketched to allow for these expansions. This perspective also enabled a closer analysis of the attachment between humans and artifacts that Eternally Yours is trying to stimulate. For attachment to come about, artifacts should be present in an engaging way. They should stimulate users to participate in their functioning, thus forging a bond between users and the machinery of artifacts. Engaging artifacts are not present simply as generators of commodities. Their materiality cannot be avoided because humans have to enter into a relationship with the product itself, not only with what it *does* for them. And only if the product itself matters – instead of its "meaning", "image", or "functionality" – will it be less likely to be readily discarded. Its meaning, image, and functionality can also be procured by similar products.

Understanding the attachment between humans and artifacts requires an attachment of actor-network theory to phenomenology.

## Notes

1 I mention his work here, even though Latour recently renounced the name "actor-network theory" because of the misleading associations that have become connected with the concepts of "actor", "network", "theory", and even the hyphen between "actor" and "theory" (Latour 1999b).

2 More information about Eternally Yours can be found at: http://www.ecomarket.net/EternallyYours.

3 Ihde uses this term for his "praxis-perception model" of phenomenology, in which phenomenology primarily concerns the perceptual aspects of human-world relations (Ihde 1993, 3, 7; Ihde 1990, 30). In his introduction to postphenomenology, he indicates that his phenomenological model can be ranged

among the "posts" that have developed in philosophy, because of its pluralism and nonfoundationalism (1993, 1). He does not elaborate on the implications of this turn for the methods and characteristics of the phenomenological approach itself, however. That is why I try to do so here, by setting out the keynotes of what I think postphenomenology should consist of.

4 *"Tout l'univers de la science est construit sur le monde vécu."* (Merleau-Ponty 1945, III)

5 *"Il s'agit de décrire, et non pas d'expliquer ni d'analyser."* (Merleau-Ponty 1945, IV)

6 In this context, "world" indicates "disclosed reality": or a reality as it is present to humans in concrete situations, not "reality in itself".

7 This postphenomenological idea of the mutual constitution of subject and object escapes Latour's criticism on phenomenology in *We Have Never Been Modern.* Latour maintains that, by connecting them to each other over the bridge of intentionality, phenomenology confirms the "poles" of subject and object instead of refuting them. Postphenomenology, however, sees the two poles as the product of the intentional relation between them, not as pre-existing subjects and objects. Subjectivity and objectivity arise from their interrelatedness, instead of being presupposed by it.

8 See Latour (1993b, 39) for an extended use of this kind of annotation.

9 See also Verbeek (2001).

10 See Heidegger (1986, paragraph 15 and 16).

11 See also Verbeek and Kockelkoren (1998).

# Art and Technology Playing Leapfrog: A History and Philosophy of *Technoèsis*

*Petran Kockelkoren*

## Technological mediation

### *The relation between art and technology*

Down through history, the relationship between art and technology has assumed many guises. With the present-day rise of new media and technologies, new art forms are appearing which are often situated outside the traditional circuit. The body and its prostheses are highlighted in performances, and the visual arts often link up with industrial design and ICT applications. The formerly sharp dividing line between autonomous and applied art is gradually disappearing. Despite the increasing influence of technology on art, one still speaks of the autonomy of art. The relationship between art and technology is not without friction in contemporary art, but has it ever been problem-free? Contrary to generally held views that ascribe to the artist an almost innate autonomous position over and against cultural processes in which new technologies are adopted, artists actually tend to be accomplices to these social developments. Artists have always played a leading role in appropriating the new ways of looking and hearing that innovative technologies have offered. Technologies that open up new forms of experience have been domesticated and made manageable by artists. It is not an entirely innocent process. In fact, it can best be characterised as a disciplinary process in which the senses are culturally disciplined and the body is conditioned to match. Through the role they play in the embodiment of technology, artists are an accessory to such disciplinary processes.

The central question in describing the relationship between art and technology is that involving the nature and scope of technological mediation, since this is where this relation is fleshed out. Mediation takes place as soon as an artifact articulates our sensory relations with the world around us. Initially, the current sensory disposition is tipped off balance. That event is enveloped in new images and metaphors until a new balance is attained, one that incorporates the technology that caused the disruption in the first place. When new technologies are introduced to the public for the first time, a period of decentring commences: a period in which the users do not know what to make of the technology and the world to which it gives access. But it does not take long before recentring strategies are set in motion to domesticate the technology in question. I shall examine the interaction between technological designs and the artistic imagination in more detail.

The thesis that art above all contributes to the domestication of mediatory technologies is a bold one. This thesis is not without its problems, for it runs counter to a cherished image of artistry which holds that the artist adopts an autonomous position vis-à-vis cultural processes. As an independent observer, he exposes the alienation brought on by technology. But I am now claiming that the artist himself, perhaps in spite of himself, is an accessory to strategies of cultural stabilisation. My argument in defense of this thesis boils down to the following: I hope to be able to demonstrate that the notion of autonomy itself is the product of technological mediation. If that is so, the so-called autonomous position outside the cultural flow is untenable, because, in that case, the autonomous position itself is an exponent of a prior disciplinary process. It implies that the more the artist puts up a fight against cultural necessity, the more he complies with it, unless we can redefine autonomy in the light of technological mediation. In that case, autonomy is no longer a point of departure, but rather a result that has to be constantly won from discipline.

### *Train sicknesses and the embodiment of technology*

A good example of the disciplining of the body and the cultural pathology it entails is provided by the introduction of the train in the 19th century. When people started to travel by rail, there were soon reports of a whole battery of train sicknesses, of which the railway spine became the most famous. It was a controversial diagnosis. On the grounds of spinal damage, though it was difficult to prove, it was possible to claim damages from the insurance companies of the day. This complaint reached epidemic proportions in England in the 1860s and spread from there to Germany and the United States. Even the Netherlands was not immune. After a few decades the epidemic died down and disappeared from medical discourse, almost without trace.[1] What was its significance?

At first, the symptoms were described in purely somatic terms. There were reports that railway personnel suffered from eye infections and diminution of vision, and that passengers were affected by miscarriages, blockages of the urinary tract, and hemorrhages. But there was soon a shift to mental disorders. A Bavarian physician, for instance, wrote: "Travel with some steam engines should be prohibited for medical reasons. The rapid movements will produce mental disturbance. Rail travellers will succumb to brain damage, or 'delirium furiosum'" (Schivelbusch 1977, 113). Railway disorders proliferated in the psychiatric domain. Siderodromophobia was one of the more exotic variants, referring to the general disorientation accompanied by physical discomfort that seems to have affected the first rail passengers en masse.

What happened can best be described using a cultural historical interpretation of corporeality. The body is not some universal substratum on which cultures graft their different linguistic attributions of meaning from above, as it were. In contrast, the senses are prone to historical fluctuations. They are constantly in motion because they are the points of anchorage of cultural reeducation. This can be deduced, for example, from a comparison of the sensory perceptions of the first rail passengers with those of less well-to-do hikers of the same era.

The hikers see and hear the wind blowing in the fields of corn, they smell the grain, while the horizon rises and falls to the rhythm of their footsteps. The different senses confirm one another: the hikers see what they smell and what they hear in a harmony of the senses known as synaesthesia. However, as soon as they step into a carriage and the locomotive starts up, that synaesthesia disintegrates. What they smell is not what they see, they hear the rattle of the wheels on the rails, the horizon slips smoothly by, devoid of any relation to their own body. The disorientation that inevitably results has been well described by the poet Victor Hugo, who sent an account of the experience of his first journey by rail in a letter to his daughter: "The flowers by the side of the road are no longer flowers but flecks, or rather streaks, of red or white; there are no longer any points, everything becomes a streak; the fields of grain are great shocks of yellow hair; fields of alfalfa, long green tresses; the towns the steeples, and the trees perform a crazy mingling dance on the horizon; from time to time, a shadow, a shape, a specter appears and disappears with lightning speed behind the window: it is a railway guard" (Schivelbusch 1977, 55-56).

What is near flashes by, what is further away seems to revolve on its axis as soon as you stare at it. All the while, the body remains motionless. It took a while to appropriate the new experience, but after a few decades the disorientation and the rail sicknesses it produced disappeared. A new synaesthesia had been established, this time by embodying the train as a moving medium of perception. That process of embodiment could still produce individual traumas, but they were exponents of a collective cultural process of learning. The orientation from a moving train challenges the previous, culturally established habits of viewing. People had to appropriate a new, technologically mediated sensory regime. At first they became decentred, then they learned to recentre themselves through the simultaneous embodiment of the train. Such stabilisation processes are not once-off, but keep on recurring as new technologies appear.

New technologies and the revelatory experiences they promise are often first explored by artists and presented to the public in the form of artistic events and fairground attractions. At any rate, that is what happened with the train. The World Exhibition held in Paris in 1900 included an attraction that imitated the sensory disorientation of the train. The members of the public were put in imitation compartments and landscape scenes were unrolled opposite them. These had been painted on three layers differing in height, one behind the other, representing the foreground, medium distance, and background, respectively. Each of these panoramic scenes was unrolled at a different speed; the one at the front relatively quickly, the one in the middle more slowly, and the one at the back very slowly. The simulated journey followed that of the famous Trans-Siberian express from Moscow to Peking and lasted forty-five minutes. Simpler versions, using a smaller number of rolls, were presented at village fairs. Some of them lasted two hours (Hyde 1988). Artists often worked as the accomplices of fairground entertainers as the painters of these rolls. People stared at the exotic panoramas and, in doing so, appropriated the art of perceiving in motion.

The industrial revolution was also an artistic challenge. The Impressionists and Post-Impressionists already included industrial objects in their idyllic canvases. Monet's locomotives, wreathed in clouds of steam, are legendary. The founder of Orphism, Robert Delaunay, painted airplanes with revolving propellers, and on more than one occasion he tried to paint a helicopter view, but from the top of the Eiffel Tower. Futurism pounced on the speed of the new means of transport. Just before the First World War broke out, Giacomo Balla and Umberto Boccioni painted moving scenes from speeding trains and cars. The Futurists did not confine themselves to orderly exhibitions, but they also organised rousing lectures and tumultuous Futurist theatre events in the big industrial cities of Northern Italy.

Although the fair and the theatre have been described as refuges from cultural conditioning, they were actually the reverse: they functioned as cultural normalisation machines par excellence. Processes of cultural appropriation of this kind have taken place in an unbroken succession all through history. At a recent fair near my home on the German border, there was a centrifuge and a pulsating cabin that promised a blood-curdling plunge on a virtual roller-coaster. The widespread distribution of phenomena of this kind throughout the centuries means that human sensory perception is historically determined from start to finish. Our perceptions have always been completely mediated by technology. There is no underlying, original substratum. There is only a permanent oscillation between decentring and recentring, with mediatory technologies as the engines of change.

## Natural artificiality

### *Human ex-centricity and its entanglements*

We handle historical mediations by embodying technology in a process of decentring and recentring. In trying to clarify the relationship between mediation and decentring/recentring, I shall fall back on the philosophical anthropologist Helmuth Plessner. Plessner explained this complex of phenomena in terms of his philosophy of human "ex-centricity" (Plessner 1928). People are "ex-centric" because unlike animals, they do not coincide with themselves. They distinguish themselves from animals by their very capacity to distinguish themselves from animals. They do not want to be confused with them. They are able to distance themselves. They can even stand beside themselves and look over their own shoulder, as it were, at everything they do. People are outsiders in relation to themselves. So human ex-centricity also entails their mediated access to the world. Because of their involvement at a distance, people do not have direct access to the world around them. Their senses are always culturally mediated by language, technology and art. People are "naturally artificial" by virtue of their ex-centricity. Technology cannot alienate people from their naturalness, because they are already alienated by virtue of their very condition. Language, technology, and art teach people how to articulate and even to celebrate their ineradicable alienation.

Mediation and decentring/recentring are intrinsically related to one another because they are both rooted in human ex-centricity. Ex-centricity, not coinciding with oneself, is an a priori fact of the human condition. People cannot become ex-centric, they already are ex-centric. Plessner himself was very reticent on the question of the historicisation of ex-centricity. He was afraid that it would open the door to a linear model of cultural development, from a primitive state of coinciding with oneself to a modern state of decentred existence. According to this kind of model, earlier cultures, in which artisanal mediations dominate, are "primitive" by definition, while more decentred cultures, in which machines and automata mediate, are considered, for that very reason alone, to be "more developed" or even "more rational". Plessner would have nothing to do with this kind of deprecation of traditional cultures, because they no more coincide with themselves than we do. He never tired of driving home the point that even prehistoric humans lived a decentred life. However, one of Plessner's followers, Lolle Nauta, broke Plessner's embargo on the historicisation of ex-centricity by claiming that human ex-centricity is both an a priori fact and a historical voyage of discovery. That voyage of discovery presupposes successive, technologically mediated processes of decentring which, in turn, are only possible at all by virtue of that ex-centricity (Nauta 1986, 64). In this view, technological mediations have at least the status of being one of the driving forces of the process of human self-discovery.

For the time being, we know enough about the inextricable connection between technological mediation and the processes of decentring and recentring to be able to continue our analyses of historical mediations. However, an important question that has to be raised in order to clear the way for an inquiry into the relation between art and technology is the question of whether or not technological mediations have a determinant character. It would be extremely naive if we suddenly regarded history as being entirely caused by technological mediations. A historicisation of the idea of human ex-centricity must not be allowed to boil down to changing signs. Cultural history has been identified with the history of ideas for a very long time. Replacing the primacy of ideas by that of technology would be tantamount to exchanging one determinism for another.

There is no a priori reason why technologically mediated processes of decentring and recentring should necessarily move in the direction of increased rationalisation or the development of higher values. Human ex-centricity means that technological mediation plays an important role in every opening up of reality in a broad historical diversity. New technologies open up the worlds that correspond to them and require the development of corresponding images and meanings. They need not necessarily be mutually compatible, nor need they develop in the direction of an ultimate truth.

### *The co-evolution of technology, image and meaning*

Cosmologies derive their validity and its limited scope from the mediatory technologies with which they are entwined. In retrospect, Marx turns out to have been right after all in claiming that the infrastructure (the relations of production) determines the superstructure (the world of ideologies), but he is only right to a limited extent. In the present-day conditions of technological pluralism, we no longer espouse the linear causality that was a characteristic of the era in which Marx lived. New technologies do not "cause" new ideas.

Marx's thesis that the relations of production determine ideas is in need of differentiation. For that purpose, we can make good use of the notion of technoèsis.

The capacity of technology to open up reality and to give shape to culture has been called technoèsis by Roy Ascott, philosopher of the new media (Ascott 2000). Noèsis, a word of Greek origin, means "act of cognition". In this view, knowledge is considered not as passive registration, but as an active turning towards the object of knowledge. That activity may also entail technological mediation with the requisite corporeal adjustments. So technoèsis is an act of cognition via technology or the technologically mediated formation of images and conferral of meaning.[2] In other words, we learn to perceive and to attach words to what we perceive in a culturally conditioned way through technology. The category of technoèsis covers those phenomena that occurred at the introduction of the train, for example. Contrary to what Marx thought, technoèsis does not lead to massive alienation. After all, in the philosophy of mediation, there is no natural substratum to fall back on. Recentring does not lead us back to some unspoiled, primeval state, but at most, it brings about a temporary state of equilibrium in a process of technological mediation.

Instead of embracing a naive technological determinism, we need to situate technoèsis in a manifold co-evolution of technologies, images and ideas. The technological design process is driven by interested groups that gradually have to create a basis of support for their approach and have to recruit scientific and economic aid for that purpose. During its development, a new technology is surrounded by numerous visions of the future and guiding metaphors that only gradually crystallise into a presentable technological product. The product still has to stabilise after its introduction on the market. There is no one best way of technological adaptation. What we see instead are processes of interlocking design and stabilisation. Every technology is surrounded by a nimbus of images and metaphors that guide the development of that technology and must eventually help to domesticate it.[3] In the meshes of that process, we seek the space in which artistic imagination ties in with technological design.

The contribution of artists is not an intervention from outside, nor does artistic design only point the way in processes of domestication after the event. The formation of artistic images and technological design evolve in parallel. Images, technologies and even scientific theories emerge in a social process, and that process is not marked by monocausality. That is why I prefer to speak of the co-evolution of technological design, the formation of images and the conferral of meaning – in other words, technoèsis. It is not a deterministic process. It allows room for artists to manoeuvre.

### *Weak versus strong technoèsis*

A weak and a strong variant are possible in accounts of historical cases of technoèsis. We have already considered the example of what happened when the train was introduced. The weak variant only indicates how new metaphors are deployed. The train that speeds through the night without ever stopping at the stations that flash by soon appeared as an archetype in psychoanalytical dream interpretation, a discipline that owes its vocabulary to the 19th-century metaphor of the steam engine and hydraulics. Without them, thinking in terms like emotional overload and the multi-layered model of the personality (in which deeper layers are penetrated and dragged up to the surface for rational inspection) would not have gained validity.

Piet Vroon and Douwe Draaisma (1985) present the history of psychology as an alternation of guiding metaphors consistently derived from dominant technologies: from the clock or timepiece, via the steam engine, telephone switchboard, radio and radar, to the calculator and the computer. The different metaphors cover theoretical areas that are mutually exclusive, but outdated metaphors are occasionally brought back into use to refer to newly discovered areas. It might also be the case that metaphors derived from older technologies cover a more adequate theoretical field than more modern ones for certain evolutionary layers of the brain. So metaphors and entire figurative languages do not succeed one another historically in a straight line, but overlap.

However, this kind of loose, more associative version of history is not yet sufficient for us to be able to speak of technoèsis in a general way. We are discussing the cultural manipulation of sensory perception, and in that case, it is not enough for technologies merely to appear as topics of conversation. We must try to find cases of the genesis of key philosophical concepts through mediatory technologies in which those concepts then come to apply to those technologies in a domesticating way. The dominant philosophy of a particular period should be articulated by metaphors provided by the technological instruments and equipment of that era. That is the strong variant we shall explore further.

## Autonomy as an exponent of technological mediation

### *The "autonomous subject" as a product of linear perspective*

A strong example of technoèsis is the birth of the autonomous subject in the Renaissance. This example has been widely discussed ever since the art historian Erwin Panofsky tackled the theme of the historical genesis of the autonomous subject. The notion of autonomy defines the individual as the source of meaning and as the point of accountability of experience. This view of autonomy, according to Panofsky (1991), depends directly on the practice of perspective painting in the Renaissance. Panofsky argued that linear perspective was not only the formalisation of a natural use of the senses, but rather introduced a new sensory regime to replace the medieval variant. The rules for drawing in linear perspective were first drawn up in practice by Filippo Brunelleschi in 1425 and laid down in the treatise on painting *De Pictura* by Leon Battista Alberti, which was published in 1435/36. Most Westerners have been familiar with the organisation of our field of vision according to the regularity of linear perspective since infancy. What we perceive is arranged within a clearly delineated frame, with the eye focused on a single, central, disappearing point situated on the horizon.[4] How does that arrangement of the picture affect our orientation to the world around us?

Through the application of linear perspective, the world is transformed into an external scene, while in the same movement the viewer, who was initially a part of it, is dragged backwards out of the picture and turned into a remote spectator. The technique of perspective mediates between the spectator and the natural scene; the two poles are generated as opposites through that very process. At some point, the spectator allows himself to be portrayed as a large figure against a landscape in the background. A new sensory regime has taken root. The autonomous subject is born. Descartes signed that birth certificate with the well-known dictum: "I think, therefore I am", thereby proclaiming the autonomy of the subject. According to Panofsky, there is a direct connection between the technique of perspective painting and the later Cartesian view of the subject.

Panofsky's theory of the cultural genesis of the subject was subsequently embraced by philosophers who drew attention to the alienation produced by technology. In their view, it is hardly surprising that we have been saddled with an environmental crisis.[5] A detached subject was created in the Renaissance. Those circles always put the blame on Descartes, claiming that, for a Cartesian subject, nature can only appear as an external scene, no more than a stock of raw materials waiting to be plundered. Although their accusations came rather late, they view the environmental crisis as being inextricably tied up with the Renaissance imposition of perspective on nature. According to them, technological alienation only became really irreversible with the introduction and rapid dissemination of the camera. This device makes automatic what initially had to be represented separately each time. The consequences are disastrous: this piece of equipment makes the world available in an end-less series of snapshots. In this way, an authentic anchoring in a site is irrevocably lost. Once the reality of events is equated with their capacity to be photographed, alienation becomes virtually unstoppable.

### *The material conditions of the history of ideas*

Criticisms of this view have been put forward by a new generation of followers and critics of Panofsky, one of whom is Jonathan Crary. Before praising Panofsky, we have a bone to pick with him first. We were trying to find an example of the material conditions of the genesis of meaning, and came across Panofsky on our quest. But the inclusion of Panofsky as a fellow traveller is misleading in a certain sense. Panofsky did argue that the practice of perspective painting laid the foundation for the autonomous subject, but he was not at all interested in the material conditions of technological mediation.

Panofsky saw the introduction of perspective not in connection with new technologies, but as an instance of the geometrification of the picture of the world. He was a Neo-Kantian who conducted a historicising investigation of how the senses in the Renaissance were subjected to a new sort of a priori rationalism. Moreover, it was precisely on that score that he came in for a good deal of criticism. He was accused of explaining the origin of painting with a linear perspective in terms of Descartes's much later epistemology, in order to present that epistemology as an exponent of the linear perspective. He was thus accused of something that historians never pardon – an anachronism. This is due to some extent to the fact that Panofsky exclusively practised the history of ideas. He was barely interested in the material conditions under which that process of geometrification could take place. A better understanding of the technological mediations at work might clarify the connection between a technique used in producing images (the linear perspective) and epistemology (the notion of the autonomous subject). Only then are they treated as co-evolving phenomena. So an appeal to Panofsky calls for a shift of theoretical ground. Panofsky's account only becomes forceful after it has undergone a materialist turn. Jonathan Crary has taken the first step in that direction.

Crary (1992) refutes those analysts who claim that the camera is an unbroken continuation of Renaissance perspective, and that there is no historical transformation between them. Renaissance linear perspective already came under fire at the beginning of the 19th century and was even replaced by a different sensory regime. The development of the Renaissance perspective, Crary argues, was dependent on the instrument of the camera obscura. This is a device that admits light through a small opening (often covered by a glass lens) into a box or darkened room to project an image of the outside world onto a surface opposite. The minuscule opening faced the outside world; the projected image was upside down. This device provided the dominant metaphor for how the eye operates and led to the formulation of optics. Moreover, it offered the metaphor of consciousness as an inner world in which the outside world is represented. Most historians have considered the later camera to be no more than a technically improved version of the camera obscura. In view of this technological continuity, the image of consciousness did not change very drastically in the intervening period. The autonomous subject of the Renaissance is thus credited with persisting down to the 20th century.

Crary sees things differently. New gadgets appeared at the start of the 19th century, and they not only required different ways of looking but also generated different kinds of subjects. The 19th century is filled with clever viewing devices and toys, such as the thaumatrope, zoetrope, kaleidoscope, and stereoscope. All of these gadgets differ from the camera obscura in that the latter installs an uninvolved observer who is condemned to passive watching, as if the retina functions solely as a legible projection screen, while all the other devices involve the senses, including sight, in a physical way. Each of them requires an active contribution by the body to the act of perception. The different kinds of active physical involvement are then taken to correspond to an equal diversity of types of subject. At any rate, it is to the beginning of the 19th century that Crary dates the birth of the scientific observer who employs a broader sensory register in his perceptions than the Renaissance observer who was limited to a visuality that simply registered what he saw.

What actually happened in the 19th century was the incarnation of the Renaissance subject. The subject created by the application of linear perspective is an abstract, universal subject (a mind's eye), instantiated in each individual, it is true, but interchangeable with any other at the same time. The 19th-century subject, on the other hand, is diverse and embodied. Subjectivity is diversified among the different senses, and distributed to different, unique, bodily centres of accountability, whereas the Renaissance canon of vision deliberately rejected physical differentiation: people were distinguished from one another precisely by their mental capacity or spirit.

The perspectivist view was dependent on the camera obscura, Crary claims. But by exclusively concentrating on the camera obscura as a mediatory instrument, he follows Panofsky in overlooking a number of materially mediated disciplinary strategies. Perspectivist vision was initially practised using a pane of glass to draw on and a visor to facilitate vision with one eye (Wachtel 1995). These material aids ensured that the painter kept his head still and that he maintained a distance from his object because the pane of glass separated them. In this way, the artist's body was disciplined, which meant at that time that the body was removed from notice as much as possible. The subjects formed in this way were purely mental subjects. At the same time, the body – like any other object – was subjected to the perspectivist gaze, or rather, it was first turned into an object by that gaze (Romanyshyn 1989).

### *Anatomy theatres and panorama buildings as centring machines*

To popularise the objectifying view of the body, anatomy theatres were set up in almost every European capital. Spectators, or people who were compelled to be spectators in them, could pay to watch anatomical dissections being conducted. Those anatomy theatres imposed a perspectivist view of the body through their architecture alone. The circular anatomy theatre in Uppsala, for instance, which was completed in 1663, was surmounted by a large dome beneath which a circle of windows admitted daylight. That light fell on benches arranged in descending rows; in the middle was the dissecting table. Maps of the world were attached to the wall behind the uppermost row of benches to enable the visitors to get used to the new bird's-eye view of the world. If people turned their backs on these maps, they could literally look down upon the anatomical section below. All the anatomy theatres looked like ex-centricity embodied in architecture. Those who did not frequent the anatomy theatres could still be confronted by some of the numerous paintings on the theme of the anatomy lesson.[6] Art and theatre had already played an important role in the Renaissance in popularising the new modes (or should I say fashions?) of sensory perception.

Once one is aware of these often-frivolous forms of education and discipline in the margins of culture, there is no need to be surprised that the 19th century presented the same picture. One difference from the Renaissance, however, was that the theatres and the emerging popular fairs now served to incarnate the subject. Stereoscopes and similar devices could be found in bourgeois drawing rooms. These viewing games mobilised a new type of bodily involvement on the part of their users. The London Stereoscopic Company, established in 1854, set itself the target of "a stereoscope for every home". Soon afterwards, the first train appeared on the scene. The body was bombarded from all sides, and had to learn to shake off its Renaissance habits. To that end, fairground attractions of all kinds sprang up in the wake of the train, and illusionism was the rage in theatres everywhere.

The 17th-century anatomy theatres were succeeded by the panorama buildings of the 19th century in terms of both architecture and function. Decentred people practiced centring themselves in a landscape in the cylindrical panorama building with a diameter of 40 meters. Dozens of them sprang up in Europe, in the capitals and along the coasts. The dimensions of the buildings were standardised on the model of the Panorama Hittorf, set up in the Champs-Elysées in Paris in 1838. Consequently, the landscape paintings were interchangeable and could travel. That these really were centring machines can be seen, for instance, from the Great Globe (1851/62) in Leicester Square, London. Inside the gigantic globe, a four-storey staircase was constructed from which the interior could be viewed – an inside-out model of the earth. The continents could be taken in at a glance from the centre of the globe (Bätschmann 1984). Panorama Mesdag in The Hague, which first opened its doors in 1881, has been preserved down to the present. The panorama it presents is an artificial dune landscape on the coast of Scheveningen; the real landscape could be seen a stone's throw away for nothing, but people felt lost in the face of the sky and the sea. The fact that they queued up to see the same landscape inside the panorama confirms the idea of a centring machine.

### *The erosion of autonomy*

Crary has little to say about these kinds of popularising processes of embodiment. He does have a lot to say about discipline and normalisation, even suggesting that it all amounts to exploitation of the workers. He acknowledges his debt to Foucault on several occasions, but fails to get to grips with the materially mediated production of bourgeois bodies. He treats the camera obscura and its 19th-century family of visual instruments exclusively as a topic of conversation for philosophers. He leaps straight from a few isolated instruments to key philosophical concepts among individual philosophers (slipping up here and there in the process).[7] We have to use our own imagination to conjure up the parallel processes of embodiment with their technoètic dissemination. Crary does offer a lot of evidence to support a technoètic historiography, but his own contribution to it requires rewriting in that direction. That would add more cogency to his claims.

The Renaissance subject acquired form through the techniques and practices of linear perspective and the camera obscura. The techniques of linear perspective made the subject a detached observer. The camera obscura equipped the subject, metaphorically, with an inner, independent world. That inner world was shaken up when people started to travel by rail. It is no surprise because the sensory regime installed by the Renaissance was aimed at the fixation of the gaze and the freezing of an exterior scene for inspection. The view from the railway carriage imposed very different demands. However, none of the different regimes can claim to present "natural" sense perception or to be more "natural" than the others. People are simply naturally artificial, and artists teach us to live with the fact, for better or for worse.

New technologies are explored by artists for their potential to create images, and are domesticated in the process. At the same time, the same technologies are investigated by philosophers and writers for their metaphorical potential. Technoèsis runs its course. I have thrown some light on the creation of the notion of the autonomous subject as an exponent of that, as well as on its relative validity, throughout all its techno-historical transformations. The notion of technoèsis does indeed appear to be a fertile heuristic guideline for the writing of history, but, to repeat, if I present artists as the accomplices or even the vanguard of normalising and disciplinary cultural practices, what is left of the renowned autonomy of art and artists, especially as it is the very concept of autonomy which provokes the necessary historico-philosophical doubts?

In the Renaissance tradition, the idea of autonomy was projected backwards on to the ideas of classical thinkers like Plato and Aristotle. In this way, the autonomous subject was credited with an eternal existence, as if autonomy were an innate highest good. After tracing that luminous idea back to antiquity, Renaissance philosophers then claimed to have rediscovered it, and drew themselves up in battle order to defend it. Thinkers of the Enlightenment regarded the so-called rediscovery of this idea as a sign of progress in history – or rather, history was defined as rectilinear progress. But now that we are in a position to make the necessary historical corrections, the whole notion of innate autonomy and progress turns out to be no more than an exponent of the mediations of the time. The retroprojection of these ideas into classical antiquity was used to legitimise the regime of central perspective that was striving to achieve dominance. At the same time, however, a number of rival sensory regimes were operative that were excluded or relegated to the sidelines by this strategy of legitimisation. Those alternatives were no less valid in themselves.[8]

If we rewrite history in terms of technoèsis, it not only becomes possible to trace the Renaissance back to its material technological conditions, but the same also applies to the alienation thesis from the second half of the 19th century to the second half of the 20th, and to the idea of technoèsis itself. The idea of alienation and the correlative claim of the original nature of man are exponents of industrial mass production with its risks of cultural leveling. The ideas of natural artificiality, technological mediation and technoèsis then become exponents of the technological pluralism of the second half of the 20th century. Since a technological pluralism constantly preserves a certain degree of decentring, this furnishes the historical context for the idea of human excentricity.

The huge question now facing us is that of whether or not it is possible for autonomous artists to maintain a critical relationship to the multiple disciplining processes from which autonomy and other concepts arose. According to the Romantic view, artists expose technological alienation from an independent position. Is this viewpoint valid now that we have disposed of the idea of alienation, as Plessner did? And what does it mean if the artists themselves are completely caught up in rival technological mediations?

## Autonomy over and against mediation

### *The conquest of autonomy*

It will have become obvious by now that the concept of autonomy is open to a variety of interpretations. It can stand, among other things, for an allegedly inalienable property, it can be opposed to alienation in the form of originality, and it can mean that a person has to win an independent position over and against heterogeneous forms of discipline. The autonomy of art and of artists means something else in all those cases.

Under the present conditions of technoètic pluralism, people are exposed to heterogeneous forms of discipline. People are free to regret the fact if they so choose, but it also entails opportunities for unprecedented freedom. At any rate, it resolves one of Foucault's profound problems. Foucault investigated normalising and disciplinary social processes. He paid attention both to the power of language and naming, and to the material forms of influencing behaviour. For instance, he pointed out how architecture forces people to move in a certain direction. He was not the first to historicise corporeality – Freud, Wilhelm Reich, Norbert Elias and J.H. van den Berg were predecessors or contemporaries who developed more or less reliable alternatives – but Foucault spoke in the name of philosophical resistance. Culture is not merely written on the body, externally as it were, while the body is a substratum that remains the same all the time; on the contrary, the body is socialised right down to its deepest sensory level. However, if discipline demands the whole of the body, from which position can one still rebel or even protest against current disciplinary practices? Does the body still hold on to a remote place of refuge?[9] Foucault had his doubts, but I am tempted to see the salvation of autonomy precisely in the pluralism of sensory regimes.

With the erosion of the claims of the Renaissance perspective to universal validity, and with the refutation of the pathos of the Romantic resistance to alienation, space is created for a critical deployment of human ex-centricity. It is precisely in the friction between the heterogeneous forms of discipline that arise from that ex-centricity that the possibility arises of adopting an autonomous position vis-à-vis any regime. People express themselves by means of mediatory technologies, but they must also reclaim their autonomy from the embodied technologies by virtue of their ex-centricity. We all win our autonomy from the spectacles, artificial hips, pacemakers, mobile phones, cars, televisions, etc. that have become a part of us. And at the same time we owe our current notion of autonomy precisely to technological mediations of this kind. That is the double bond of natural artificiality. Every technological piece of equipment contributes to the definition of its user. For instance, we may well wonder what kind of subject is installed by television. William Uricchio from the University of Utrecht is currently performing research in that area. In disagreement with Crary, he claims that television is the successor to the camera obscura and that this appliance continues to produce the Renaissance subject, whether we like it or not (Urichio 2000). He may be right. But, fortunately, we simultaneously undergo the influence of numerous other devices that prescribe something else.

Artists are also exposed to such heterogeneous influences. They explore the access to reality that devices offer by trying out a new visual language for it. They do not create their art on the basis of some deep, essential core that is less accessible to ordinary people, and from where they can resist the alienation of the masses. Plessner's philosophy of ex-centricity shows that people do not have any essential core at all. They have to turn themselves into what they are by artificial means. People are alienated by their very nature. They are, paradoxically enough, constitutionally lacking a foundation. By virtue of that, autonomous art can only be that form of art which places a walkable platform above our constitutional lack of foundation. It can do so by testing the mediations we require for that. In that way, art is an accomplice to the diffusion of conventional forms of disciplining, but at the same time it represents a critical potential to resist them.

What is the nature of that critical potential? What is its anchor point? The Renaissance tradition has passed down to us a view of aesthetics according to which it is merely a question of formal characteristics that can be distinguished in an exclusively visual pattern. But that very notion was itself technologically mediated and was based on a particular sensory regime that prescribed a reduction of the senses to the visual. If we give pride of place to technological mediation, criticism must consistently focus on the specific point of contact between technology and the senses, because it is a question of repeated embodiment and the corresponding adequate technoèsis. That is why we have to start and end with the senses and their mediated nature.

## *The telestereoscopy of the moon as a mediated mediation*

Many artists experience the medium in which or with which they work as an obstacle to be overcome. They do not want to be hindered by the material they use. Most of the artists who come to the university for technical support in overcoming those material obstacles delegate the task to engineers, so that they only need to concern themselves with the "artistic" side. This establishes a division of labour that turns the artist into a visionary walking on air, and burdens the engineer with a rather uncreative task; after all, he is only made responsible for the practical implementation of the artistic idea. The capacity of technology to shape culture is entirely ignored.

Technology is more than an instrument for the expression of prior images and ideas. Media like the film camera and the video recorder also do more than passively record what appears in front of the lens. For the artistic expression to do justice to the medium deployed, the preconceived functional aspect of the technology must be investigated and surpassed with the help of the media used. But only too often, the limitations of the equipment used determine the visual idiom that it produces, without itself being thematised. The device is embodied, disappears from the field of attention, and is neutralised as a frictionless "go-between". The artist can then make a free choice from the media at his disposal for the implementation of his preconceived ideas. All the same, investigation of the technological mediation itself is not without precedent. The 19th-century discussions of the verisimilitude of stereoscopic images show that mediation was noted, and even exploited by artists and scientists. My source here is *Instruments and the Imagination* by Hankins and Silverman (1995). Among other things, they offer an epistemological analysis of the mediation of perception by the stereoscope.

In the 19th century, the discussions on the merits of instruments of perception were couched in terms of fidelity to nature. Both the scientific and the popular views of the stereoscope shared the background of natural theology that was widespread at the time. In that view, God had designed the human senses perfectly for the correct perception of nature. The stereoscope was initially welcomed as the instrument that was an improvement on the perspectivist representation of nature on a plane surface – whether in paint or in photography – in terms of verisimilitude. All the same, right from the outset, there were opponents who pointed out the mediated character of every perception and the inevitable transformations that are the result of it.

A discussion of the distance between the camera lenses that made the two photographs required for stereoscopy is illuminating. If fidelity to nature is regarded as the norm, the distance between the lenses must correspond exactly to the distance between a pair of human eyes. That norm was indeed vigorously defended by the orthodox advocates of natural theology. Any deviation from it was treated as heretical "distortion", a term which only has meaning in relation to a standard, "natural" way of looking that was considered to have been given by God. At the same time, however, others saw ways of using the stereoscope to expand the field of human vision.

The success of stereoscopy proceeded parallel to that of the earliest photography. Both technologies appeared to be able to guarantee the authenticity of what was shown. But photographers in particular engaged in fierce discussions of what the medium could contribute to visual inquiry. In landscape photography, for example, cameras placed at a distance from one another were used on a large scale for stereoscopy. The effect of the artificially increased distance between the lenses on the stereoscope was that the representation of the landscape displayed much more depth and the mountains were apparently much higher than was possible with a "natural" distance between the eyes, but at the same time the landscape seemed to have been miniaturised and imprisoned in a viewing box. Hermann vom Helmholt nevertheless elevated his invention, telestereoscopy, to the status of a scientific research instrument.

The stereography of the moon by Warren de la Rue in 1858 was the climax of artificially heightened relief. The moon always presents the same side to the earth, so that we can only guess about the relief of its surface. However, if the moon is photographed twice with an interval several months in between, a difference in standpoint is created between the two moments. This made it possible to exploit the effect of the libration (the wobble of a heavenly body) of the moon, since the libration also causes a slight difference in the angle of exposure. Consequently, the relief was heightened in stereoscopy with photographs taken at large intervals from one another. De la Rue compared the effect with the vision of a giant whose eyes are thousands of miles apart. He defended his method as follows: "We may be well satisfied to possess such a means of extending our knowledge respecting the moon, by thus availing ourselves of the giant eyes of science". With these words De la Rue appeals to Sir John Herschel, who added: "Lunar stereography entails a step out of and beyond nature".[10]

The step "beyond nature" can be understood in two ways: it may be regretted as a loss of authenticity, as the orthodox view had it, or it may be welcomed as a calling into question of the authenticity of every standpoint. In the latter case, the "natural" way of looking appears fortuitous, and the distance between the eyes of a human being interestingly becomes interchangeable with that of a fly or a giant. The bottom line or the absolute benchmark in something "natural" thereby ceases to have any meaning and disappears. That is exactly what happened in the discussions in the 19th century. Initially, natural theology functioned as the benchmark, and it clung to the unmediated body. But that insouciance was belied in the discussions of mediation. Mediation became an interesting object of inquiry in its own right.

### *Autonomy in new media*

Anyone who takes photographs today or makes use of other image mediators has to justify the type of mediation used in his visual idiom. Autonomy shows itself in a critical handling of such mediation. Unfortunately, many artists today are guilty of an instrumental view of media, in which the media are seen as neutral means of recording; people are simply free to choose from them, depending on the ease of representation and transmission. In the meantime, however, their own practice often belies the way they put it into words. With the rise of new media and technologies, new art forms have emerged. Fine art is linked with industrial design, website design, architecture and spatial planning, or it characterises itself in performances, street theatre and pop culture.

The new appraisal of artistic exploration of technical mediation means that the mediating technologies themselves can move into the limelight. Perhaps the main reason for the awkwardness of the relation between art and technology is the principle of "remediation". New media have the tendency to swallow the older media, to transform them, and to recapitulate them in a different form (Bolter and Grusin 1999). The talking film was a combination of the telephone, camera obscura, magic lantern, camera, and phenakistoscope. The typewriter went through several transformations before it was absorbed by the word processor. The personal computer repeated the typewriter before bringing photographic and film editing on to a different plane.

The phenomenon of remediation is not new; it already occurred when writing was replaced by printing. But today the remediations are tumbling over one another. Old films are transferred to video and then broadcast on television; video is replaced by DVD, television news by the Internet, and so on. In each transformation that takes place, however, specific characteristics of the older media are lost. One of the first explorations of video as a medium showed a man trying to escape from the television set; it looked like someone trying to escape from a box. When this video is projected on to a wall via a beamer, the whole effect is lost. A video show cannot match the rattling of the film projector in the intimate darkness of the cinema. That is why it is necessary to keep not only the film rolls and videotapes but also the equipment for which they were made. Now that generations of equipment succeed one another at such a fast rate, and rival systems are often in circulation, it is no easy task to keep and show medium-specific works of art.

Remediation does not only apply to the equipment; the embarrassments and contradictions connected with authorship are also a case in point. Nowadays interactive works of art are put on the Internet. They change as a result of the login of the viewer, who thereby becomes a co-author. The medium and the user increasingly define one another. A similar process is taking place in commercial visual communication. It used to be called "applied art", to distinguish it from its élitist counterpart, autonomous art, but nowadays both of them depend on teamwork in media laboratories where they have to take their orders from the same machines and automata. Art is increasingly and ubiquitously becoming an interactive process that can no longer be delimited and isolated. All the same, video artists still sometimes try to preserve the notion of the original creative artist, by signing their videotapes and releasing them in limited issues, for example. However, in that case, they are resorting to rituals of demarcation that were already established by art printing and photography, in spite of the fact that such willful limitations were and are not specific to those media either. Apparently, artists often slip back into outmoded framings of autonomy.

To sum up the results of my analyses: artists are involved in technological mediations and the intrinsically related disciplinary processes. Their autonomy is an exponent of such processes that they themselves have helped to pioneer. There is a Baron von Münchhausen effect in the freedom that they have managed to win vis-à-vis technological mediations, for they do not elevate themselves from some Archimedean point or other outside the flow of mediations, nor from a predetermined core or source of autonomy. They implement their ex-centricity in process, as an intersection of influences subject to economic and political pushing and pulling. The vessel is renovated as it sails. Engineers can launch the offshore process better with the artists as equal partners – after all, art and technology are leapfrogging over one another all the time everywhere. When artists and engineers co-operate, they are – hopefully critical – agents of cultural decentring and recentring processes.

## Notes

1 See Schivelbusch (1976), Luijf (1990), Siemerink-Hermans (1998).

2 The concept "noèsis" or act of cognition was used by Husserl to refer to the intentionality of the consciousness. The correlate of such an act of cognition is the "noèma", that which is cognised. Unlike Husserl's emphasis on pure conscious-

ness, the term "technoèsis" stresses the mediated character of every act of conferring and understanding meaning.

3 Bruno Latour's Actor-Network Theory was developed as a rival to this sociological approach to technology, known as the "Social Construction of Technology" (SCOT). Latour not only thematised the social formation of images and the conferral of meaning connected with technology, but also, and above all, attributed a directive role to the technological artifacts themselves. There are thus several rival theories at work here. See Bijker (1995[a]) and Latour (1993[a], 1993[b]).

4 See also Crosby (1997).

5 The connection between Renaissance perspectivism and the current environmental crisis was made in the Netherlands by Ton Lemaire (1970). Although I do not share the pessimism of his diagnosis, my interest in the subject was aroused by this exemplary book.

6 Rembrandt painted two anatomical lessons. The *Anatomical Lesson of Dr Deijman* was later damaged by fire in the anatomy theatre in the Weigh house (Waag) in Amsterdam. Since the organisation of an anatomical lesson involved expenses, people had to pay to attend it. A 1625 ruling fixed the rate at 6 *stuivers* per corpse for members of the guild, irrespective of the number of days that a lesson lasted, and 4 *stuivers* for outsiders. The *Anatomy Book* of the Guild of Surgeons records that the anatomical lesson of Dr Deijman in January 1656, which lasted three days, raised the sum of 187 guilders and 6 stuivers. Although it is impossible to determine the precise number, this seems to indicate that between two and three hundred people came to watch in the dissecting room every day! (Middelkoop 1994, 11).

7 For incisive criticism of Crary's philosophical digressions, see Atherton (1996, 139-165), Batchen (1991).

8 See Jay (1988, 3-23).

9 Foucault (1976), Zwart (1995). See also the comments on this by Schermer (1996, 81-85).

10 From Hankins and Silverman (1995, 171).

# The Politics of Agency

# Taking the Socio-Technical Seriously
## Exploring the Margins for Change in the Traffic and Transport Domain

*Boelie Elzen*

### Introduction

A well-functioning traffic and transport system is a necessity for an industrialised and complex society. At the same time, the way our traffic and transport system is shaped and functions also causes major societal problems. Emissions of pollutants from vehicles worsen the quality of the air, causing health hazards to humans and other living species. Emissions of $CO_2$ in particular contribute to global warming. The continuously increasing number of vehicles makes it ever more difficult for traffic to proceed smoothly, causing congestion, limiting the accessibility of many destinations, and threatening the livability of cities and other living areas.

These problems have been on the agendas of public authorities since the 1960s. In general, these problems have been split into behavioural and technological problems. Emissions are regarded as a technical problem because the engine technologies and the fuels used discharge hazardous substances. Congestion is primarily a behavioural problem caused by people travelling (too) much and/or choosing an inefficient means of travel.

These problem definitions strongly determine the search for solutions. Emissions are primarily made the problem of the vehicle industry which is requested, or forced by means of legislation, to develop cleaner engines. Congestion is primarily tackled by making an appeal to people's sense of responsibility to society via awareness campaigns that request them to travel less or to make greater use of public transport.

Over the past decade, though, policymakers as well as many others have become increasingly skeptical about the possibilities of influencing people's mobility. At the same time, interest has grown in technical options to tackle congestion problems. There appears to be a shift from the behavioural approach to the technological approach. However, this shift has not remained uncontested. A variety of actors, especially those concerned with the environment and the livability of cities, continue to emphasise that only a change of behaviour on the part of travellers can lead to fundamental (or sustainable) solutions for traffic and transport problems.

From an STS perspective, this distinction between technical and behavioural problems and approaches is not only strange but also counter-productive. STS research has extensively shown that technical change and societal or behavioural change typically go hand in hand. New technologies rarely just replace existing ones. They also have new characteristics and new qualities that influence the behaviour of users and other relevant actors. The personal computer, for instance, was not developed as a typewriter, but once on the market, it made the typewriter obsolete in just a few years, while at the same time drastically transforming office work.

In this chapter, I propose a strategy aimed at improving the integration of technical and societal/behavioural changes. To that end, I start by presenting a framework of analysis that distinguishes different forms of socio-technical change, depending upon the degree of behavioural change associated with it. Subsequently, I argue that, especially in cases where a considerable degree of behavioural change is desired (in traffic and transport, for example), a learning strategy on the potential of new socio-technical configurations in experiments is crucial. I subsequently present a number of cases to illustrate some potential findings from this kind of strategy. In the final section, I indicate how the approach can be optimised, and I end by concluding that this kind of approach takes the socio-technical nature of innovation much more seriously than current transport policies do, and also has a larger potential to solve transport-related problems.

## Different forms of socio-technical change: optimisation versus renewal

In the past few years, an enormous range of technical options has been developed to tackle societal problems related to traffic and transport. Some of these can be relatively easily fitted into the existing system, while others require an extensive adaptation of the behaviour of producers as well as suppliers and users of transport services. The former type of solutions receive far more attention and are taken far more seriously than the latter.

An "easy-to-fit" option largely means that travellers do not have to change their behaviour, the assumption being that the vast majority will never forego using their private car. For this reason, battery-powered electric vehicles (BEVS) are not considered a serious option since these vehicles only have a very limited range on a full battery. This option would require an adaptation of traveller behaviour (e.g., using this vehicle only for short distances and using a train or hired car for occasional long distances). In contrast, fuel cell electric vehicles (FCEVs) do not have this range limitation and are widely considered the "ultimate transport technology" of the future. This view is prevalent despite the fact that, at present, FCEVs are much more expensive than BEVs, the technology is far more complicated and problematic, and infrastructure issues are also more complex. The general assumption is, however, that the technical and economic problems of FCEVs can be solved, whereas the behavioural problems linked to BEVs cannot.

In this chapter, I challenge this neglect of potential behavioural change by highlighting some aspects of the socio-technical nature of innovation processes. To characterise the current situation, I use the notion of a *socio-technical regime* (or just "regime": Kemp et al. 2001), in this case, the traffic and transport regime. A regime may incorporate one or several systems in a variable mix, such as the private car system and the public transport system in this particular case.

Regimes are not static but inherently dynamic. Innovation takes place continuously within the regime, but it tends to be conservative with incremental changes. The current problems of the traffic and transport regime, however, require more radical changes to achieve sustainability. In discussing the possibility of achieving this, I distinguish two main routes, namely, "regime optimisation" and "regime renewal", which can be characterised as follows (Elzen et al. 1996, 1999):

- Regime *optimisation* relates to innovations that can be fitted in relatively easily. This may concern improving either the public transport system or the car system. Changes are largely technical in nature, requiring little or no adaptation of the traveller.
- Regime *renewal* relates to attempts to change regime relations more fundamentally through innovations with new characteristics. Examples are new transport modalities (like door-to-door public transport concepts) or new forms of ownership (e.g., car-sharing). A crucial distinction with regime optimisation is that in the case of regime renewal, the behaviour of various actors in relation to various relevant technologies changes considerably; travellers need to do different things to reach their destination.

The distinction is largely a matter of degree. STS research has convincingly demonstrated that innovation is always socio-technical in nature. Still, for the purposes of this chapter, the distinction is useful since it helps to distinguish the current situation from what is needed.

Regime optimisation is current practice. This is implied in a self-fulfilling prophecy that assumes that it is futile to try to change people's travel habits and their love of (using) their private car. Innovations that do not fit the current pattern encounter a lot of skepticism and have difficulty in attracting funds. This optimisation approach has succeeded in achieving a drastic reduction of vehicle-polluting emissions but has been very ineffective in tackling congestion. Measures aimed at the latter (such as new infrastructure) afforded merely temporary relief, with problems popping up some time later or elsewhere.

In contrast, regime renewal has a much larger potential for problem-solving, which is not surprising since, in this case, the thinking starts with the type of behaviour that is considered desirable from the societal perspective, whereas regime optimisation takes current travel behaviour as a starting point.

A variety of innovations that would fit a renewal perspective have been proposed. The problem with such innovations is that they do not fit the current regime, either on technical grounds (e.g., because of the lack of appropriate infrastructures) or on societal/behavioural grounds ("I am not going to share my car with others"). Small-scale introduction can occasionally be realised, but innovation can only give substantial relief when applied on a large scale. Such upscaling to realise regime renewal requires interaction between a variety of new elements. Thus, the problem is not so much the development of new technologies but the tuning and the societal embedding of them.

### Experiments as a breeding ground for new socio-technical configurations

Regime renewal in itself is nothing new. The current traffic and transport regime, for instance, differs drastically from that of 50 years ago when cars had a minority share of traffic. The question is whether it is possible to induce regime renewal and guide it in a direction with far fewer societal problems. To answer that question in full is beyond the scope of this chapter, but I shall provide a part of the answer by emphasising the need to learn via socio-technical experiments.

Regime renewal is difficult to realise because a large set of interrelated barriers impede radical change. These may include:

- technological factors
- government policy

- cultural and psychological factors
- market factors
- production factors
- infrastructure and maintenance
- the possible undesirable societal and environmental effects of new technologies.

Despite these barriers, history shows that radical change may still take place because new technologies, although not (yet) ready or able to compete with existing technologies, are initially developed and experimented with in "protected spaces". The new technology is protected by various actors who believe in its long-term prospects and who are willing to invest time, money, and effort in "making it work", in both technological and social terms. Such protected spaces are called "technological niches" or just "niches" (Kemp et al. 2001).[1] These niches are experimental situations characterised by a "learning by doing" approach. By trying out a variety of changes, an attempt is made to lower or overcome the diverse obstacles.

Across the world, experiments are currently being performed utilising a wide variety of transport innovations, in pilot or demonstration projects. All these experiments involving a specific technology (such as electric vehicles) collectively make up a technological niche. A major problem is that many such projects within the niche are once-only affairs with little mutual exchange of information. A deliberate strategy can then be followed to learn across these projects within a niche and, as a next step, to use this knowledge to define further experiments attempting to integrate findings. This requires the co-ordination of the activities of a wide range of actors. The (policy) approach targeting this co-ordination is called *strategic niche management*, SNM (Weber et al. 1999; Hoogma et al. 2001). In the SNM approach, the general objective of experiments is to learn how new technologies and their societal embedding can be mutually attuned.

Looking at past and ongoing experiments (usually called "pilot" or "demonstration projects"), the vast majority of these have a strong bias for technical (and economic) factors, and neglect the behavioural side. This, however, side-steps the major problem since one of the most "wasteful" characteristics of the current regime is the individual use of a single vehicle from door-to-door for any kind of purpose. The challenge, therefore, is to organise learning in experiments in such a way that it teaches something about the potential for behavioural change.

To illustrate what this may render, I shall describe some experiments with transport innovations, focussing on what they may teach with regard to options for renewing the traffic and transport regime. These examples are not mainstream, in the sense that they do not easily fit the current regime, and most transport experts find them rather uninteresting. For the purpose of this chapter's argument, however, they are all the more interesting since their technical drawbacks induced innovative thinking on the behavioural side.

### Introduction to the cases

I shall explore this further through the analysis of three recent experiments with electric vehicles (EVs). Electric vehicles fit into the current traffic and transport regime very poorly. Energy is stored in large batteries that weigh several hundred kilograms. Despite their large mass and volume, they give the vehicle a range of only 50-100 km, after which the battery needs to be recharged. In most cases, this takes 6-8 hours, although with expensive equipment this can be speeded up to approximately half an hour. The large batteries are expensive, costing several thousand euros for a typical vehicle, and may have to be replaced one or more times during the vehicle's lifetime, depending on the battery technology. This long list of negatives has made skeptics argue that EVs have been, are, and always will be the technology of the future. So why bother?

Their major advantage is that they produce no polluting emissions. That is why they are also referred to as "zero-emission vehicles" (ZEVs). Emissions do take place at the power plant producing the electricity, but there they are less harmful to humans than the emissions of vehicles in the cities. Even taking power plant emissions into account, the overall emission from EVs can easily be 50-80% better than that of conventional vehicles, in part depending on the type of power plant.

This low level of polluting emissions stimulated the US State of California to pass legislation in 1990 decreeing that, by 2003, 10% of vehicle sales from the major car manufacturers should be ZEVs.[2] All through the 1990s, the major car manufacturers fought this requirement on the ground that EVs were more expensive and performed a lot worse than conventional vehicles, and that they could not possibly find customers for them. Implicitly, they thus argued that EVs did not fit the then current traffic and transport regimes.

Interestingly, though, this "technical drawback" of EVs led to innovative thinking on user behaviour in connection with these vehicles. Various experiments were set up in which EVs were used in a way different to conventional vehicles. I briefly discuss three of these projects below, notably a 6-year project with "lightweight electric vehicles" in Mendrisio, Switzerland, an experiment with a "self-service" EV short-term rental system near Paris, and a comparable but less ambitious scheme in Turin, Italy. I have studied these cases in depth, along with many others, within the framework of an EU-funded international co-operative project under the name of UTOPIA.[3] The results of these analyses can be found in Zwaneveld et al. (2000) and Ricci et al. (2000). The brief descriptions below are partly based on these sources, partly on other sources indicated.

### Case 1: Mendrisio – LEV market stimulation[4]

*Experimental set-up*

In the early 1990s, the Swiss Federal Ministry of Energy (BEW – Bundes Energie Wirtschaft) launched a program called "Energy 2000" to promote measures to stabilise the consumption of fossil fuels and $CO_2$ emissions as well as to support renewable energy sources until the year 2000. To operationalise this program, BEW evaluated the potential of the lightweight electric vehicles (LEVs) developed by various small innovators and concluded that such vehicles were very energy-efficient and would cause far lower polluting emissions than conventional cars.

To realise this promise, LEVs would have to be used on a large scale. A vision was developed foreseeing a LEV park of 200,000 vehicles by the year 2010, i.e., 8% of the total car fleet. As a medium-term goal, the energy consumption of these vehicles should be equivalent to 1 to 1.5 liters of gasoline per 100 km, roughly five times as energy-efficient as conventional cars.

After considering various alternatives, it was decided to realise a large-scale experiment in one community plus a number of smaller experiments in so-called "partner communities". One of the main objectives would be to explore the effects of a range of promotional measures. Thus, the "Großversuch mit Leicht-Elektromobilen" (large-scale experiment with lightweight electric vehicles; in short "Großversuch") was defined (Muntwyler 1997).

In December 1994, the community of Mendrisio, in the southeastern, Italian-speaking canton of Switzerland, was chosen to host the large-scale experiment. In Mendrisio, the LEV target of 8% of the national car fleet by 2010 would already be realised in 2001. The experiment was to start in 1995 and be divided into 3 two-year project stages. Each project stage would be evaluated on the basis of the adjustments to be made. This would allow for flexibility in the project plus a safeguard that it could be stopped at an earlier point if the results were too meager.

Over 50 promotional measures were identified for the experiment. Most noticeably, the purchase price for LEVs would be subsidised by 30-50%, depending on vehicle performance. Lightweight vehicles are not defined by their weight but by their energy efficiency (which is strongly correlated). Electrically assisted bicycles and motorcycles are also subsidised by 50%, while all other types of EV are subsidised to a maximum of 30%.

The total budget for the Großversuch was 33 million SFR, just over € 20 million. About 65% of the budget was used to subsidise the purchase of vehicles, while close to 10% was for the set-up of an infrastructure. The remainder was reserved for project management and concomitant research. Firms wanting to sell vehicles in the experiment had to lower their sales price by about 10%. Furthermore, the canton and the community guaranteed 17% (Schwegler et al. 1994).

The Großversuch was not only a pilot and demonstration project, but also a research project. It was considered to be an unconventional, large-scale practical test on a scale of 1:1 (Schwegler et al. 1994). An intensive research program was conducted to analyse the effects of specific promotion measures.

### *Results*

In mid-1999, four years into the project, the number of vehicles sold lagged somewhat behind target. In the following two years, sales went up considerably, and by 30 June 2001 the number of LEVs sold amounted to 395, 45 more than the target of 350 (Meier-Eisernmann et al. 2001).

A more important goal was to demonstrate the usefulness of LEVs in everyday life and to learn which support measures would help LEVs on their way toward market success. Most of the project participants were satisfied with their vehicles, even though the range of the vehicles was often smaller than promised by the dealers. The reliability of the vehicles appeared to be good, and the vehicle costs were considered fair, which implies that the official price of the vehicles (without federal subsidies) was still too high to introduce the vehicles in an open market.

Concerning support measures, three two-year stages for introducing LEVs on to the market were distinguished. In the first stage, people's interest in LEVs was evoked by giving them the possibility to test the new technology. In the second stage, the financial disadvantages were reduced, and an infrastructure was realised. Finally, in the third stage, a good after-sales service was set up, and experts such as local garage owners were further educated.

LEVs are a good example of how new attributes from new technologies can induce people to behave differently to what they themselves might expect. For instance, *ex ante* surveys indicated that LEV users across Switzerland evaluated the new option of individual mobility as an *addition* to their existing options. Since most household travel involves short trips, the LEV became the most frequently used vehicle. For a variety of reasons (e.g., quietness, environmental friendliness, novelty) people started to prefer the EV to their conventional vehicle, and they tried to avoid using the latter by planning trips more carefully. They tended to avoid long and energy-intensive trips and always sought the shortest way to reach a certain destination. Thus, they surprised even themselves, as they tried to make as many trips as possible by LEV and changed their behaviour accordingly. Most LEV users were convinced that the LEV technology was sensible and future-oriented and should be actively supported.

### *Evaluation*

The results of the Mendrisio experiment can be evaluated in various ways. One of the most obvious success criteria could be the number of vehicles sold. The set target was reached, but this teaches us little about the possibilities of and the barriers to the introduction of innovative transportation schemes. More important are the lessons involving users' mobility patterns, the environmental aspects, and the effectiveness of political support measures. The organisers of the Mendrisio project obviously shared this view, given the extensive evaluation scheme on all of these aspects. Most of the objectives were achieved in this respect.

The original goals of the experiment went beyond simply being a test project for electric vehicles. The overarching goal was to demonstrate integrated, sustainable forms of mobility in which LEVs would play an essential role. The achievement of this goal not only required a careful combination of promotional measures and technological improvements of the vehicles but also learning processes on the part of the consumers.

More important than the number of EVs sold were the insights gained in processes that support the dissemination of the technology. Insights have been gained on:

- the importance of specific promotional measures. These experiences will prepare the ground for a nationwide introduction of LEVs in individual communities.
- technological questions related to the performance and environmental characteristics of the vehicles in everyday use.

The large-scale experiment with LEVs in Switzerland may be seen as a paradigmatic example of "Strategic Niche Management" (see above). Policymakers take up the initiatives of individual citizens and small enterprises and try to support the dissemination process of the technology in a non-authoritarian way. Actor-learning, networking, and expectation management are active parts of the project set-up. The framework of the experiment is flexible, and communication and monitoring receive major attention.

A major point yet to be resolved, however, which will be analysed in a follow-up project, is the question of the relationship between the experiment and the real market. Should the experiment be a testing field, a kind of laboratory in which components of a system are tested, or is the experiment a kind of a simulation tool in which "critical paths" have to be identified? In the former case, the problem field consists of a number of "valves and regulators" which have to be fine-tuned to achieve results. In the latter case, qualitatively different routes may be taken, and the experiment has to identify these routes and to determine the trade-offs they imply.

Although the LEV market share is virtually negligible in the overall Swiss mobility spectrum, there are interesting indications that this new type of vehicle may change mobility patterns. Although the LEV technology relies on automobile technology and LEVs are located "at the doorstep" (unlike, for instance, car-sharing projects), users have to adapt their mobility patterns to this new technology. They must learn how far they can drive on a battery charge and how long it takes to recharge the batteries. Because of these limitations, they have to make a conscious decision whether or not the LEV is suited for a certain trip. It makes people more reflective on their travel needs and more open towards various options to satisfy those needs. In short, their thinking becomes less automobile-centred.

## Case 2: Praxitèle – An advanced EV self-service system[5]

### *Experimental set-up*

The initiative for Praxitèle was taken by CGFTE, a French public transport company operating nationally. In 1989, CGFTE organised a discussion meeting with passengers seeking to identify "the ideal transport concept". Among several alternatives, a concept based on self-service rental cars was seen as a strong option. It was believed that this kind of system could combine the advantages of cars with the advantages of public transport. A practical set-up should guarantee a parking place for the car user, be easy to operate, and use non-polluting vehicles.

After several (feasibility) studies and interaction with other French companies and ministries, this idea evolved into the Praxitèle concept. Praxitèle is a self-service EV rental system. It is based on a fleet of small vehicles – the Praxicars which are located in specific areas called the Praxiparcs. The whole system is supervised with the help of a central computer, the Praxicentre.

The experiment, the first of its kind, started in October 1997 in the "new town" of Saint-Quentin-en-Yvelines, an outlying Paris suburb, about 15 km from the centre. It has 140,000 inhabitants and two expanding industrial zones and is considered the second most important business area in the west-Paris region. It is linked to Paris by an extensive motorway system as well as a fast urban train line (RER).

Fifty EVs, electric Renault Clios with a 70-km range, were available to the public. In the long term, a novel vehicle specifically adapted to city use (a small, lightweight energy-efficient EV) is also being developed. The vehicles were eventually located in 15 different stations at strategic places in Saint-Quentin-en-Yvelines like railway and bus stations, shopping and business centres, hospitals, etc. A car could be taken any time from any of the stations, used freely as if it were a private car, and then returned to any of the stations. It could be used by several drivers during a day, which reduced the required parking space in the city centre. Drivers only had to have a valid driver's license and register as a member the first time they used the system. From then on, members could use the car as they liked, much as they would their own private vehicle, getting in by means of a bankcard-like "Praxicard". Each client was automatically billed at the end of the month for the time s/he had actually used the service.

The fleet of Praxicars was controlled by the Praxicentre, which informed users about the nearest available vehicle via Praxi terminals or phone. It used new telecommunications and localisation systems that were considered necessary for the success of the system, since earlier experiments with self-service cars had failed due to the lack of efficient fleet management. Each vehicle was equipped with a GPS-based positioning system allowing the vehicle to locate itself with a precision of about 30 meters. The Praxicentre also handled reservations and transfers to other types of transport (train, bus, taxi).

The project partners were CGEA Transport (CGFTE's parent company), Renault, EDF, Dassault Electronique (now Thomson CSF Detexis), and the Municipality of Saint-Quentin-en-Yvelines. Especially the participation by Dassault is interesting, as it has no tradition in the transport business. Dassault primarily produced military electronics, but with the collapse of the market for military equipment, it started to look for new markets in which to diversify from early 1990s onwards. Companies in this kind of position tend to be more open to innovative approaches in a new field where they face less established competition.

The project budget was FF 30 million, just over € 4.5 million, of which 50% was paid by the partners and the remaining 50% by the Ministry of Transport, other French agencies, and the European Commission. The broad objective of the Praxitèle experiment in Saint-Quentin-en-Yvelines was to demonstrate the usefulness and economic feasibility of an individual public transport system based on a centrally managed fleet of small electric vehicles.

### *Results*

The experimental phase of Praxitèle officially started on 16 October 1997 and was concluded in early 2000. From the evaluations, it appeared that a significant number of people had used the service. In May 1998, 400 members had registered, a number that was to double one year later. In the one-and-a-half years since the start of the experiment they had made 25,000 trips, covering an average distance of 8 kilometers in 15 minutes. In April and May 1999, the average use was about 500 trips a week, i.e., about one-and-a-half trips per car per day.

Users indicated they were very satisfied with the service. A growing group of clients became regular users as they learned how to use the system in real-life practice. They changed their transport behaviour, especially when they had no regular access to a private car. Users particularly appreciated the freedom, the ease of use of the self-service system, and the availability of cars without worries about maintenance. They valued the fact that the cars were electric, as an expression of their environmental concerns.

The main problems were related to the experimental and innovative features of the service. Continuous adaptations were made during the experiment to solve the technical problems that were encountered. Concerning economic aspects, it was evident from the beginning that the scheme would not be economically feasible. The costs of EVs, because they were not made as a mass product, were far too high, while an economic break-even point was not expected with a scheme with less than a few hundred vehicles. At the very least, the experiment has proven that there is a substantial demand for this kind of service. How this demand can be satisfied in a cost-effective way is as yet unclear, as detailed economic evaluations have not yet been made.

Initially, it was feared that the system would compete directly with taxis, and there was even a threat of resistance from taxi driver unions. In practice, taxis have not experienced a loss of clientele. The self-service system was a complement to existing public transport systems that may have taken away some customers from taxis but may also have increased their client base by creating demand for a taxi in cases where there were no self-service vehicles available at a specific station when needed.

The managers of the project were satisfied that the technical feasibility of the system had been proven and that more detailed results should help define the conditions for successful implementation of the service. Larger-scale projects are being considered for other sites, and a project has been proposed for Paris with some 2,000 cars. In the longer term, an operator should be able to offer cities and public transport authorities a service based on this type of self-service system. The Praxitèle experiment suggests that there is a place for a self-service car system in urban transport.

### *Evaluation*

Within the framework of an EU-funded project on strategic niche management, interviews were held with a variety of people who worked on the Praxitèle project (public bodies and partners in the experiment). In these interviews, two main issues emerged: the funding and the technical complexity of the experiment (Simon 1998).

One crucial aspect of the Praxitèle project is the large number of technological innovations incorporated in the system, including:

- the non-contact smart card that offers easy access to the cars and facilitates fare collection;
- the automatic connection with the inductive charger;
- electric vehicles;
- real-time communication between the vehicles and the management centre; on-board electronics to control the vehicle, assist the driver, and calculate the trip cost;
- mathematical models to optimise the redistribution of cars among Praxicars, and the recharging process of electric vehicles; and
- multimedia terminals installed in the Praxiparcs to assist the users, e.g., to call a vehicle when required.

Many of these innovations were not standard technology for most users of the Praxitèle system or its operators. It was quite risky to include so many innovative technologies in a transport system that was itself a radical innovation as a transport concept. The increased risk of technical failure could have had a negative impact on the perception of users who could confuse the usefulness of the concept with the way it functioned. This also raised more problems in assessing user satisfaction and the functioning of the system.

To avoid these risks, a less ambitious set-up could have been chosen, by drawing upon certain car-sharing systems that incorporated very simple technologies and operated quite well, for instance. However, this might have invoked other problems. For example, if conventional cars had been chosen rather than EVs, there might have been a problem in finding a suitable location as most municipalities were primarily interested in transport projects with "clean" vehicles.

The initiators of the project were well aware that it was risky because it involved a wide variety of new elements: a new transport concept, various new technologies, an unusual combination of network partners. Several partners were among the largest firms in France, yet they were not willing to invest large sums because of these risks. As a consequence, the Praxitèle consortium looked intensively for public support. Also in this strategy, the project risk proved to be a major hurdle that delayed the experiment for almost two years. The industrial partners wanted public authorities to commit themselves to the project because the project would be so innovative (and, consequently, risky) while public authorities were also reluctant to give major support for the same reason.

Eventually, the project was funded in spite of much opposition. There were technical problems, but the service did work well enough to allow an exploration of the concept in a practical situation. It appeared that a substantial number of users valued it as a useful and environmentally friendly complement to public transport. These drivers form a very small minority in relation to the total number of car users, but the results legitimise designing a larger-scale follow-on project to explore how this kind of concept can be transformed into a service useful to many.

### Case 3: Elettra Park – the Turin automatic electric car rental[6]

*Experimental set-up*

The quality of the air in the city of Turin in the early 1990s was considered to be rather poor. A substantial part of this was attributed to extensive car use. Noise was also considered an important nuisance. The Turin city authorities felt they had a responsibility to reduce $CO_2$ emissions and the associated greenhouse effect. To tackle these problems, the city supported a project with a number of EVs that were made available at rental stations on the periphery of the city where people had arrived by other means. They could rent the EV for a limited period to serve their needs in the city, bring it back to the station, after which it would be available again for use by others. To make this type of scheme functional, it had to be transparent and easy to use.

The experiment, named Elettra Park, was started in 1996 as a joint venture between the Turin City Council, ATM (Public Transport Company), AEM (Electricity Company) and Fiat. Elettra Park consisted of 22 electric Fiat Pandas that could be rented automatically from a public parking area. The parking lot was on the edge of the city centre, was easily accessible by public transport, and had separate sections for EVs and conventional vehicles. The EVs could be used only within the urban area, from 7.00 a.m. to 10.30 p.m. every day of the week. The cars had room for two passengers as the battery took up the entire rear seat room. The battery allowed an urban range of about 50-70 km and then took 8 hours to recharge.

Customers first had to sign a contract at the permanently staffed office and pay a deposit. The customer then received a chipcard that stored a prepaid budget. At the parking lot, the customer could use her/his card to open the door of an EV and subsequently use it. After use, the vehicle had to be returned and parked in any of the spaces designated for EVs. The minimum rental fee was 3500 lira (approx. € 1.8) for up to one hour of use. After this period, an additional fee was charged per minute at a rate of 3500 lira for the second hour and 5000 lira for each additional hour. The fee included rent, electricity, third-party liability and motor hull insurance, and parking fees for the EV in the city as well as for the customer's own vehicle in the designated area in Elettra Park while s/he was using the Panda Elettra.

The project consisted of two stages: the first stage, from 23 September 1996 until the end of 1997, was to test the "basic features" of the system, and a second stage that went until the end of 1999 with a new cost and regulation structure. Turin City Council announced the availability of the cars through a variety of means, such as advertising on billboards, in public offices, at the university, etc.

The total budget was 2 billion Italian lira (about € 1 million). The funds came from the City Council, an institutional environmental project, and Fiat. The main learning goal of the project was to test the users' acceptance of a new individual and public transport system. Data on the system's performance were continuously collected by monitoring the technical operation as well as customer behaviour and feedback. The latter info was collected through surveys and telephone interviews, and all data were processed by a local transport research centre, CSST.

### *Results*

During the project, information was collected on numbers of customers, patterns of use, behavioural aspects, and opinions on the initiative. In the first stage of the experiment, until 1 January 1998, almost 2000 cards had been sold to users. Peak sales occurred in the first few weeks, with 800 cards sold in the first month, dropping to an average of around 10 new customers a week after one year. In total, during the first stage, close to 12,000 trips were made covering over 200,000 km. This corresponded to an average of 27 trips a day. On average, each vehicle was rented for about three hours a day, in which it was driven for about 1.2 hours. This rate of use was about 50% higher than that of the average privately owned conventional vehicle in Turin.

To learn about possible changes in overall mobility patterns, an analysis was made of where the users came from and of the transport means used to arrive at Elettra Park. The majority of users lived nearby and walked to the parking area. About one quarter of them used public transport, while a small minority exchanged their own conventional vehicle for an EV at the transfer point. The vehicles were mostly used for shopping and running errands, while a minority of the trips were for work purposes. The users indicated the Elettra Park scheme had two attractive features, namely, that parking was free and that the EV, because of its zero-polluting emissions, was allowed to drive in areas closed to most other traffic.

Overall user satisfaction was decidedly positive. Over 50% of the users stated that the system was good, while 22% judged it as excellent, and none of those interviewed gave an overall negative judgement. The operations involving the borrowing and returning of a vehicle, which appeared to be complicated in the design phases, were judged to be easy; there were no problems with the management of the card, and the fees were considered fair.

The most serious points of criticism were the opening hours and waiting times. Over one-quarter of the customers felt that the system should be open longer during of the day. Furthermore, right at the outset, it appeared that the demand was higher than the availability of vehicles. Because of this, some people abandoned the system, but most liked it enough to wait for an EV to return. Also, the more frequent users got used to the system as time went by, and learned when the chances of obtaining a car were the highest.

### *Evaluation*

As an experiment, Elettra Park has been in operation for several years, and as a transport service, it has become a part of the living habits of a good number of Turin residents. It is an interesting case because it looks at the technical as well as the behavioural aspects of mobility. It has rendered knowledge on the potential of a public transport service using personal vehicles and, in some cases, on how to combine this service with the use of a privately owned conventional vehicle.

The experiment has yielded several important insights, such as:

- it has demonstrated the feasibility of a system of instant rental of vehicles operating under conditions of complete autonomy;
- it has demonstrated a significant interest in a transport system with minimum environmental impact and has created, in particular, renewed interest in electric vehicles;
- it has been accepted by a large (perhaps too numerous) group of users who had no difficulty in subscribing to and using the service;
- it has shown that many urban trips, for various reasons, can be made with vehicles with limited autonomy;
- it has found its specific market niches of optimum use within the context of the need for mobility in city centres.

The project also demonstrated the need to improve specific features of the scheme, such as the correct size of the car fleet to guarantee an efficient service. A more technical facet, already anticipated, was the need to reduce the recharge requirement in order to increase a vehicle's daily autonomy. Towards the end of the project, on the basis of the initial findings, the Turin City Council developed plans to create four other transfer points in the city for an interchange between conventional and electric cars.

The overall experience was quite satisfactory, and there were only minor technical problems. The technical aspects of the electric Panda and its recharging infrastructure were judged quite positively. In general, user satisfaction was also very positive. They confirmed that electric cars provided a comfortable mode of transport and that the set of privileges granted to stimulate their use (free parking, the possibility of driving inside limited access zones) made it interesting and attractive.

## Relevance of empirical findings for sustainable mobility

In the common view, battery-powered electric vehicles will not play a very serious role in the greater traffic and transport regime. At best, they are considered an intermediary step towards further innovations like hybrid electric vehicles (that combine an internal combustion engine with an electric drive) or fuel cell electric vehicles. This bias in thinking, however, is caused by seeing EVs as a mere substitute for conventional vehicles. Interestingly, these "technical drawbacks" have led various actors not to think in terms of improving EVs but in terms of changing the behaviour of travellers. Thus, technical change is used as a lever to evoke behavioural change.

The Praxitèle and Elettra Park projects clearly feature a vision of a new transport concept. They can be considered as specific examples of novel individualised public transport systems. EVs are not just seen as a vehicle to replace the existing car but as a new transport mode to be used in conjunction with other modes. Although less explicitly, this is also reflected in the Mendrisio experiment, e.g., by offering a railway pass to EV owners.

In all of these projects, users were fairly positive about the vehicles and the set-up. The users of the Elettra Park confirmed that electric cars provided a comfortable mode of transport and that the set of privileges granted to stimulate their use (free parking; possibility to move into limited access zones) was interesting and made it attractive to use a modal chain. The technical aspects of the electrical Panda and its recharging infrastructure were also judged quite positively. Praxitèle has also stimulated a change in traveller behaviour towards intermodality. At the very least the experiment has proven there is a substantial demand for such a service.[7]

What do these findings imply for sustainable mobility? It should be acknowledged that it is too soon to make firm claims about the wider potential of such schemes. Still, it can be illuminating to speculate a little on the possibilities of these concepts stimulating a transformation of regime. Experiences with pioneer users and the users within the Mendrisio experiment suggest a role for LEVs in a future, more environmentally benign mobility system. Most LEV users initially bought their LEV as a second car. Subsequently, however, the first car declined in importance, and the attitude towards individual mobility became increasingly open-minded and less "automobile centred". As LEVs are able to cover short distances and are best suited for regular trips, which are easy to plan, they would be an ideal complement to car-sharing (to satisfy the occasional need for a long-distance ride) or public transport.

Elettra Park and, especially, Praxitèle have demonstrated that these schemes provide a useful link in an intermodal mobility chain for various users. In various national and EU policy plans, functional intermodal chains are seen as a major promise to reduce the dominance of the private car. This would be a very environmentally friendly and energy-efficient scheme, especially if these schemes included LEVs. This would thus provide an important step towards sustainability on several dimensions.

Thus, in contrast to the common view presented at the start of this section, these experiments have rendered positive results on the potential of EVs as part of a sustainable mobility regime. They do so because they have *not* taken current travel behaviour as a starting point but have exploited the "technical drawbacks" of EVs to induce a change of behaviour.

### Inducing and guiding socio-technical change

The previous section raises the question of the wider relevance of these results for inducing change towards sustainable mobility. Thus, the first issue is to optimise learning in experiments so that it renders useful information on the potential of a combined technical and social/behavioural change. The second issue is to use this knowledge to stimulate the wider uptake of new options, which implies a change in the roles of various actors.

#### *Learning in experiments*

A wide variety of alternative transport options have been tested in many countries around the world. They include new propulsion technologies (electric, hybrid, natural gas, bio-fuels), new vehicle types (electric and power-assisted bicycles, city-cars), new transport concepts (people movers, on-demand services, personal public transport), new ownership configurations (car-sharing). The findings of these projects were usually ambiguous, often indicating some promising features as well as barriers to practical use.[8] This variety of options is called the "portfolio of promises" (Elzen et al. 2001, 186-191). A promise in this case means that an option has certain characteristics that, when fully exploited, would offer a far more sustainable solution to (some of) our traffic and transport problems than current "mainstream developments". Each of these options, however, also has problems that prevent it from being used on a large scale.

In such a situation, it is not wise to cut the knot now and focus only on a few of them. It is important to first explore the potential of a variety of options further and to combine the findings of different experiments in order to be able to assess the potential under different circumstances. Because the results of past projects were ambiguous, it is important to design proper projects to learn more about the potential and feasibility of various options, the world in which they have to function, and the measures that need to be taken to mutually adjust the technologies and the social environment in which they have to be produced and used.

Looking at the learning processes of past and currently ongoing experiments, the subject of learning is usually far too narrow. Most experiments are either seen as the final step towards implementation, even when there are many unknown issues, or they are a once-only affair without a clear vision on how to use the results for the next steps. Because of the focus on direct implementation, most projects also have a strong emphasis on the economic aspects. However, this makes little sense with regard to more radical innovations since transport concepts, user behaviour, and vehicle characteristics will only become clear in a longer iterative process of socio-technical change. The optimal vehicle in a Praxitèle-like scheme, for instance, is not the heavy type of EV used in the experiment but, more likely, a very small, relatively lightweight vehicle with a rather limited range that could be much cheaper than current vehicles on the market. Assessing economic aspects on the basis of the current experiment is therefore highly unrealistic.

In terms of the subject of this chapter, current experiments have a bias towards technical (and economic) factors, not acknowledging that innovation is a co-production process in which the social and the technical facets are both subject to change. However, this is a missed opportunity since, in some cases, the behavioural side may provide the largest potential to achieve societal goals.

Another major flaw in current practice is that experiences from different projects are not combined. Individual projects hardly ever build further upon the experiences gained elsewhere, and results are not made widely available. Evaluation reports from different projects use widely varying evaluation methodologies attuned to local interests, making it very difficult to draw generalised conclusions by comparison. This creates a barrier for a process of collective and accumulative learning.

This would be much improved if at least some of these evaluations were to follow some standard guidelines. These could easily be enforced by the EU or national agencies that usually sponsor such projects. From their position of power or authority, these organisations could set minimum requirements for the evaluation process. As stated above, these evaluation guidelines should address technical as well as social/behavioural issues in order to exploit the socio-technical co-construction potential to the full.[9]

### *From niche explorations to regime change*

It is one thing to develop and explore new socio-technical configurations in a niche, but quite another to implement them on a scale sufficiently large to change the existing regime. The vast majority of transportation experts and policy makers argue that such "niche experiences" are largely irrelevant since it is futile to challenge the dominance of the car. They argue that there is no alternative that has all the attractions and functionalities of a car.

However, transformation processes in the past have indicated that innovations hardly ever attract large groups of users immediately. Especially the more radical innovations are initially only used by a relatively small group of "early adopters" (Rogers 1983). In some cases they may gradually attract larger groups, either because of new features that new groups of users find attractive or because of increasing problems in the existing regime (or a combination of both). Especially in the case of radical innovations that do not fit readily into existing user patterns, we see a co-production process par excellence, i.e., there is a continuous change on the technical as well as the behavioural side: new user constituencies have new requirements, leading to some technical change that may then attract further user groups, etc.

In this respect, a first hurdle in the above-described experiments has already been taken, which is to demonstrate that a group of "early adopters" can be found, illustrating that there is more room for change in traveller behaviour than is commonly assumed. An interesting next step would be to take a closer look at these first users and to investigate what stimulated them to change their behaviour and, from this, to infer the obstacles and the opportunities with regard to attracting wider groups of users. On the basis of this type of analysis, various hypotheses might be developed, to be tested in further experiments. After further learning has indicated that a "working" socio-technical configuration can be developed, an attempt can be made to scale up by means of regular market processes or via government stimulation or regulation.

This, of course, is easier said than done. We face a whole new set of problems, since what we need to deal with is not just the sale of a new technology but the development of a new socio-technical configuration on a large scale, which requires a whole set of changes, such as new vehicles, new services, new infrastructures, new user patterns, new regulations, etc.

A starting point on how to achieve this could be to look at the policy instruments that have been used in the past to tackle traffic and transport problems, including:

- regulation (e.g., safety and traffic rules, emission standards);
- financial instruments (taxes and subsidies);
- infrastructure provision.

These instruments have been used with some success, especially to curb polluting emission, but they have proved rather ineffective in stimulating behavioural change. In the 1990s, it was increasingly acknowledged that the latter would require, among others, more open and participatory policy making processes. But the way in which this could actually be implemented, and the way a balance could be struck between public participation and political "knot-cutting" remains an open question and subject to a lot of ongoing debate and research.[10] To even capture the highlights of that debate would be beyond the scope of this chapter.

Nonetheless, the point can be made that whatever the nature of the process to stimulate wider use of specific options, the quality of the outcome increases when more options are available and have demonstrated their strong and weak points in experimental settings. This is especially true of options that demonstrate the possibility of behavioural change, since this kind of change is seen both as a necessity and an impossibility in the present situation.

### *Changing actor roles*

This impossibility is partly based on the observation that different types of actors are strongly committed to the current regime, making it unattractive, difficult or unprofitable for them to change. A closer look, however, reveals that these networks are not homogeneous. Some actors start changing their visions and roles in a way that could give new options a better chance. Let me give a few examples.

The larger car manufacturers, in particular, have become aware that the popularity of the car might mean that it is digging its own grave, particularly in urban areas. At least some of them have shown an explicit interest in longer-term visions that attempt to combine the use of personal vehicles with mass transit systems. The participation of Fiat and Peugeot in the two experiments described is a clear indication of this. In both cases, their emphasis is more on the conceptual aspects of the set-up than on the sale of the vehicles used. These industries seem to be well aware that the technical characteristics of an EV call for changes in behaviour that, in turn, will affect the design of an EV to match that new form of behaviour to an optimum degree. They realise that a mass-produced EV has yet to be defined and that such experiments could help them to do so. This is a rather uncommon type of openness towards learning on the part of the car industry, which, however, could be an important asset in the long term.

Additional support may come from industries that are facing problems in their traditional markets and are therefore looking for diversification. The participation of Dassault in the Praxitèle experiment is a clear case in point. EVs thus stimulate new thinking about transportation, which also stimulates new actors to become part of transportation networks.

Another important actor in the traffic and transport regime is the transport providers. They face enormous challenges as, on the one hand, they are urged to increase the quality of their services to compete better with the private car while, on the other hand, the tendency towards liberalisation over the past decade has forced them to work more cost-effectively, which puts a strain on quality. This strain makes some of them more open towards innovative concepts that are not just a repeat of the same old notions. This is clearly the case with the transport operators involved in Elettra Park and Praxitèle. Their participation is important in order to increase the chances that the schemes will be used in practice if experimental results actually justify this. There is a lack of transport operators in the Mendrisio experiment, making it unlikely that EVs will ever be used in or in combination with public transport schemes. It is striking, for instance, that the rail passes offered with the EVs in Mendrisio are hardly used.

Users have traditionally played a rather passive role in transport innovation. Innovations were shaped by industry and marketed partially in accordance with relevant government regulations. All that users could do was either accept or reject an innovation that was shaped elsewhere. In the three experiments discussed, however, users played a much more active role, and their views on the changes necessary to improve functionality and attractiveness were taken into account. In the Praxitèle case, user opinions even helped to identify this as a promising concept that was subsequently developed into an experiment. In Switzerland, pioneer users defined the concept of a lightweight EV. Obviously, the active involvement of users can help to define innovations that come close to their own needs. This innovative power of users, which is more radical than that coming from technology developers in many cases, can be an important asset to tackle the problems of traffic and transport.

The role of various government bodies is also changing. Many local governments in particular are fed up with the problems of massive car use. They are more open towards experimenting with radical solutions, contrary to the skeptical opinions of experts, and they are increasingly taking more drastic measures, such as closing off parts of the city for cars and only admitting "clean" vehicles. National and EU authorities are also rethinking their roles. They are displaying greater openness towards unconventional new options, although when new policies are eventually implemented, they do tend to confirm the existing situation of car dominance. One of the major reasons for this is that they believe that there are no serious alternatives "for the masses".

As was argued in the preceding section, this is partly due to the fact that lessons from a wide variety of experiments with alternatives are not combined to generate a cumulative learning process. It was also indicated how governments or their agencies themselves could fill this gap by formulating specific evaluation requirements for experiments with transport innovations. Most importantly, such evaluations should address technical as well as behavioural aspects, to acknowledge and exploit the socio-technical nature of innovation.

## Conclusion

To tackle the societal problems of mobility, most policymakers at various levels (local, national, and European) agree that it would be desirable to reduce the role of the car. Across Europe, many attempts have been made to stimulate this over the past decades. However, with a few exceptions, the results have been very meagre. One result of this is that policymakers as well as other actors in the field have become increasingly skeptical about the possibilities of changing people's travel habits. In the Netherlands, for instance, an advisory council on mobility recommended, in late 1999, that attempts to make life difficult for car users should be stopped (VROM Council 1999).

Indeed, looking at traffic and transport at the regime level, the position of the car seems unchallenged. The number of cars as well as the amount of vehicle-kilometers travelled have risen continuously throughout the 20th century. It is a paradigmatic example of how regimes tend to perpetuate themselves by incremental change, leaving some basic features uncontested.

The impossibility of changing people's travel behaviour is further supported by stated preference surveys, the most widely used instrument to scan people's transportation needs and to assess the potential of possible innovations. Such surveys, however, give a poor indication of the potential for change, as people tend to think in terms of their current needs and behaviour and the technologies they are familiar with.

What current approaches actually do is neglect the societal/behavioural side of innovation processes. By taking people's unwillingness to change their travel behaviour as a starting point, they subsequently turn this into a self-fulfilling prophecy by stimulating those alternatives that require little or no change of behaviour. Options that do require a change of behaviour are dismissed because they are considered unrealistic. This assumption is not only questionable, it also bypasses the greatest potential to tackle transportation problems.

The assumption is debatable because "hands-on" experience in experiments (in contrast to survey questionnaires) indicates that users are willing to change their behaviour even contrary to their own expectations. On the basis of the three cases described in this chapter, we illustrated that EVs, which are usually discarded because they are "technically inferior", can also be a source of innovation on the behavioural side.

With this experience, and given the magnitude of the problems encountered and the likelihood that they will worsen in view of the expected mobility growth, it is neither justified nor wise to take car dominance as an unquestioned starting point. Unsuccessful attempts to change people's travel habits in the past should not be taken as an example of the impossibility to achieve this but, rather, as an opportunity to learn something about how regimes may or may not change. Past attempts sought to tackle the car-dominated traffic and transport regime head-on, attempting to stimulate the "common user" to change his or her travel habits. It is acknowledged that people in smaller niches behave differently, but these are not seen as representative of the common user. Therefore, these niches are taken to be of little relevance to the issue of tackling the problems of traffic and transport. As a result of this attitude, there have been numerous experiments with traffic and transport innovations which have been accepted as failures, and the reports on which have vanished deep down into a drawer never to reappear.

However, the scrap heap of failed experiments is probably also a goldmine of relevant lessons, especially if we pay attention to the socio-technical nature of innovation. That these experiences are only based on small experiments should not be an argument in favour of the idea that they are invalid for larger groups. In the history of socio-technical change, there are many examples of regime transformations where the initial users were not representative of the later "common" user. The history of the personal computer is a clear case in point. The challenge is to try and understand, partly via learning in follow-up socio-technical experiments, how further developments can make the innovation attractive to larger groups of users.

Taking behavioural change serious in an experimental setting may smooth the path via which an alternative option can be used on a larger scale. This broadens the range of options to solve problems, compared to the myopic focus on technical aspects that is largely current practice. For instance, it is often argued that battery capacity is a large barrier to the widespread use of EVs. This depends, however, on what type of EV is used for what type of purpose. For instance, in a follow-up to the Praxitèle experiment, it might appear that the ideal vehicle is a small, lightweight two-seater EV that has a typical range of 50 km a day. Because it is lightweight, it is very energy efficient, and because it is typically operated at moderate speeds, the range might be realised with a 100-kg battery with a minor back-up facility to recharge (partly) some of the vehicles during daytime. This contrasts with the expensive 500-kg battery that is common in current EVs, thus largely dispelling the battery problem.[11]

The big issue, of course, is how such learning can be used to make the traffic and transport regime (more) sustainable. On this issue, we need to be modest, partly since past experiments and the way they have been evaluated have only hinted at the potential for a regime transformation rather than demonstrating it. On the basis of the cases presented in this chapter, we cannot conclude that these EV systems in their current form should be a central element of a sustainable traffic and transport system. The knowledge base to decide this upon is still far too small.

Another reason to be modest is that STS research, in particular, has demonstrated that socio-technical change is a very complicated process in which large numbers of actors and factors play a role. This makes it very difficult or even impossible to guide or steer these processes towards achieving societal goals. Maybe the best we could strive for is to "modulate" the ongoing dynamics (Rip and Schot 2002). Still, however difficult this may be, new socio-technical configurations that have been demonstrated in a niche have a better chance of "breaking through" than options that have been dismissed a priori. For that reason, the approach of Strategic Niche Management is important to broaden the range of new socio-technical configurations that work, i.e., work technically as well as socially.

In that sense, the cases do allow an important conclusion, namely, that users are willing to, and certainly do, change their behaviour when they are confronted with specific new transport options in experiments. Stated preference surveys, in most cases the most important instrument to assess user requirements, are a poor indicator of this and can never match learning from experience. The challenge, therefore, is to design a sufficient range of experiments to be able to draw more general conclusions on what is possible under which conditions.

This then broadens the range of options that have been proven in practice and may point to a variety of promising options that are too easily dismissed in current transport policy. The way in which one can actually stimulate the implementation of the most sustainable options is a follow-up issue that is beyond the scope of this chapter, but by broadening the range of alternatives, the "socio-technical" strategy sketched above can definitely make an important contribution *en route* to a sustainable traffic and transport regime.

Innovation is a co-production process in which technical as well as social/behavioural aspects change. Mainstream approaches to tackling the current problems of transport, however, neglect this socio-technical nature. Behavioural change is considered unrealistic, and current transportation policies focus on technical solutions. Although, like any other innovation, this will also evoke some societal/behavioural changes, a lot of the potential falls by the wayside in a largely self-fulfilling approach.

This becomes most clearly visible in the small-scale experiments such as the ones described above. They point to potential new socio-technical configurations that could be important in a sustainable mobility regime. Taking these lessons seriously and, moreover, designing and evaluating experiments in such a way that behavioural change may be induced may reveal more solid stepping stones for a route towards sustainable mobility.

## Notes

1 The concept of a "technological niche" should not be confused with a "market niche". The latter refers to a subsection of a larger economic market with specific characteristics, like the market for advanced sports cars. These characteristics are taken more or less to fix the size of that market. In contrast, a technological niche initially needs "outside protection" to survive. After a period of development and learning, however, the protection needs to be removed, after which market expansion becomes one of the main targets. Thus, a technological niche represents a specific phase in an innovation process, preceding market development, whereas a market niche represents a specific type of market. Cf. Elzen et al. (1999).

2 Not all vehicles need to be ZEVS. Hybrid cars (that combine an internal combustion engine with an electric drive) that can drive a certain distance on their battery may be counted as "partial ZEVS".

3 UTOPIA – Urban Transport: Options for Propulsion Systems and Instruments for Analysis. Further info can be found on the Internet: http://www.utopia-eu.com/

4 Largely based on Harms and Truffer (1998), and Schwegler and Trento (2000). Additional information can be found on the Internet: http://www.infovel.ch/

5 Largely based on Simon (1998), Bleijs et al. (1998), and Carli (2000).

6 Largely based on Carrara and Inaudi (1997, 1998) and Zwaneveld et al. (2000).

7 Various other experiments also indicate that at least certain groups of users are open to new travel options, such as the Autoplus/Liselec experiment and the Touc in France, and the ASTI minibus in the UK.

8 This is evident from a variety of projects the author has recently been engaged in, such as INTEPOL (cf. Elzen et al. 2001), UTOPIA (cf. www.utopia-eu.com), SNM project (cf. Weber et al. 1999; Hoogma et al. 2001).

9 The author is currently engaged in research to develop this kind of evaluation requirements for various types of options from the "portfolio of promises".

10 The most widely used concept in this respect is "governance" (for an overview, see Kersbergen and Van Waarden 2001). The author and his colleagues have contributed, using the concept of "Interactive Technology Policy" (Elzen et al. 2001).

11 Experience with the Touc in Toulouse underscores this point. Here, an EV is used to transport people between their homes and a supermarket, in a service provided by the Casino supermarket chain. The organisers prioritised the service they wanted to provide to specific customers, and subsequently chose the simplest EV technology to satisfy this need. The technical solution chosen was unconventional, a modified golfcart, but it did what it had to do in order to serve the needs of customers. It is considered such a success that it will be used in various other French cities in the near future as well (Guellard 2000).

# Trapped in the Duality of Structure: An STS Approach to Engineering Ethics

*Tjalling Swierstra and Jaap Jelsma*

## Introduction

There was a remarkable increase in attention given to ethical issues concerning technology in the second half of the previous century. This increase followed the deepening societal impact of technology, and the growing insight into its benefits as well as its potential for disaster. More or less parallel to this development in ethics, sociological studies started to delve empirically into the contextual development of the substance of science and technology. This latter move from the philosophy of technology towards a more empirical type of science and technology studies has lead to a growing interest in everyday practicalities of technology development. However, science and technology studies do not simply open up new theoretical avenues. We shall demonstrate that they also confront moral philosophers with some tough challenges.

Until recently, the moral philosophy of technology could be roughly divided into an Anglo-Saxon and a Continental tradition (Mitcham and Nissenbaum 1998). Within the former tradition, especially in the United States, the ethical approach has been intimately connected with efforts made by the administration to watch over technology by means of technology assessment. The main focus in this policy has been on the *just distribution* of the costs, benefits and risks of particular technological developments. In sharp contrast, the Continental tradition focussed on the cultural and moral consequences of the general dominance of technology in Western societies, and on the possible rise of a quasi-totalitarian technocracy. The keyword here is *alienation*, i.e., the situation where the subject is ruled by the object, that is, man is governed by technology of his own making. The conflict between instrumentalist and substantive conceptions of technology formed the issue of the debate between the traditions. In the former conception, technology is a value-neutral instrument that has to be wielded wisely and fairly. In the latter, modern technology embodies substantive values like control and manipulation. For that reason, existing technology has to be condemned as a whole and, if possible, replaced by an alternative, less dominating type.

In recent years both traditions have come under attack for their frequent a priori and monistic conception of technology and for their rather deterministic view of technology development. Critics maintain that both philosophical traditions neglect the internal workings of technology development, its contingency, the social influences that co-determine it, and its man-made character in general. As a result of this, both traditions lack the conceptual means for developing a strategy of effective control, waking up – as it were – with the hellhounds at the door. Therefore, philosophers of technology in general, and ethicists in particular, are advised to listen carefully to their colleagues from the sociology of science and technology (De Vries 1989). Their "science and technology studies" open up wide vistas on the inner workings of technology development. What becomes visible makes the traditional philosophy of technology difficult to maintain.

This sociological opening-up of the "black box" of technology finds its counterpart in the efflorescence of what is now called "engineering ethics". This type of applied ethics not only deals with the *results* of technology – leaving the content of technology development securely to the minds and hands of engineers – but also with the *practice* of technology-in-the-making as well. If technology is man-made, then, in principle, man can be expected to make conscious and ethical choices about the course of its development. The mission of engineering ethics is the amelioration of the practical choices engineers make, by introducing moral standards and emphasising ethical skills. Engineering ethics is a form of professional ethics. It directs itself towards engineers because they are the primary actors in the technology venture. It is they who design and develop the hardware (and, increasingly, also the software) and command the necessary technical expertise. As experts, they are in a privileged position to foresee and assess the possible consequences of their technologies. When sufficiently trained in ethics, so the assumption goes, they will utilise their influence to make better technology with less undesirable consequences for society and the environment. Thus, the core business of engineering ethics can be characterised as *helping and motivating engineers to take their professional responsibilities to heart*.[1] In the meantime, this trend has reached the policy makers. For instance, in the early 1990s, the Dutch Parliament asked the Minister of Science and Education to ensure that young engineers receive an education in ethics (see Ritzen 1991).

However, in a recent, thought-provoking article, William Lynch and Ronald Kline (2000) took a critical look at an important current within modern engineering ethics. As a discipline, engineering ethics examines and discusses issues as diverse as the avoidance of conflicts of interests, the protection of trade secrets and confidentiality, the right to dissent, professional responsibility, and the obligation to protect public safety, health, and welfare. But however broad this range of issues, much of engineering ethics has been directed towards ensuring "that engineers meet their obligation to the public … regardless of any pressures they may encounter in a corporate environment. Whether emphasising individual moral reasoning or professionally normative standards, engineering ethicists have been particularly concerned to help ensure that the engineering will resist social pressures on the job" (Lynch and Kline 2000, 197). In particular, engineering ethics focusses on cases of so-called "whistle blowing". In such cases, we meet responsible engineers who entertain grave doubts about the safety of a particular new technological project. But they are often overruled by managers who wave aside these doubts because they are propelled by conflicting goals like their own or the company's reputation, the financial consequences of not meeting contractual obligations towards associates, and so on. The dilemma is always whether individual engineers should make their knowledge of immanent disaster public, even though, by doing so, they break their vow of loyalty and confidentiality towards their employer and, more likely than not, suffer great personal cost.

Lynch and Kline wonder how much heroism we can expect from responsible engineers. Taking their cue explicitly from modern science and technology studies, they argue that engineering ethics would do better by paying "attention to the complexities of engineering practice that shape decisions on a daily basis". In this way, engineering ethics will help engineers "to identify features of their everyday practice that could contribute to ethically problematic outcomes before clear-cut ethical dilemmas arise" (197). Safety risks do not spring up overnight but are generally the result of a slow and gradual process that can and should be influenced by responsible – not heroic – engineers. The authors offer willing engineers ways to be responsible without having to be a (semi-suicidal) hero.

Our primary interest here is not so much Lynch and Kline's advice to engineers but rather why engineering ethicists are so keen on whistle blowing. According to Lynch and Kline, it is "the focus on individual or professional autonomy [that] can lead to an excessive focus on the conflict between engineers and management" (197-8). In our view, it is not the focus on *autonomy* that leads to this pre-occupation with whistle blowing, but rather the focus on the moral responsibility of engineers. Engineering ethics addresses *responsible* engineers, and it seeks to elaborate this sense of responsibility. Cases of whistle blowing are well suited to support this pursuit. This can be seen as follows.

Moral responsibility is a core theme of moral philosophy. For our purpose, however, we do not have to go into all the complexities of the debate. To be responsible for something is broadly understood as to be answerable for it. But one is not always answerable for everything. To be answerable, certain *conditions* have to be met. According to most moral philosophers,[2] and to most people in ordinary life as well, individuals can be held responsible, that is answerable or accountable, for their actions (and the consequences), if *four* conditions are met:

1 To consider an actor responsible, s/he should be imputable. Imputability is most commonly understood as being in possession of one's rational capabilities at the moment one performed the imputed action. This condition is well known in everyday experience. When someone wrongs us, we blame him or her and ask for compensation, apologies, or punishment. However, if a child, or someone suffering from a delirium, hurts us, we do not take him or her to be accountable in the normal sense. We do not blame the child or the madman, for "s/he did not know what s/he was doing".

2 The actor should actually have performed the action for which s/he is considered responsible. We stop blaming someone if s/he convinces us that, in fact, s/he did not execute the action that hurt us. In severe cases, a third party – such as a court or a jury – is summoned to find out the truth about these facts. Of course, it is equally possible to hold someone responsible for *not* having acted in a situation where s/he should have acted.

3 The actor should have acted on his or her own free will, i.e., should not have been under external pressure or hindered by circumstances outside his/her control. If someone breaks a promise to meet us at a certain time, we do not hold this against him/her if it turns out that, on the way, s/he was abducted or had an accident. Sometimes this condition is not recognised as a separate condition but is considered as implied in the first condition. In that case, a responsible person is understood as being rational and free. However, for our purposes, we prefer to differentiate rationality and free will.

4 The actor can only be held responsible for the consequences of his/her actions if these were or could have been foreseen. Few people will blame Diesel for the environmental problems caused by automobiles with diesel engines.

These four conditions spell out the conception of moral responsibility that (rightly) prevails in ethics and common sense in general.[3]

It is now easy to see that cases of whistle blowing fit in quite well with this conception of moral responsibility. In such cases, most of the four conditions are met. The brave engineer is – of course – rational, s/he can be the clear and definite cause of a particular consequence (by going public, s/he ensures that our safety will not be put in danger), and it is by and large foreseeable what the outcome of this action will be (the danger will be averted, the company criticised). Only one condition is not met. There is considerable (moral) pressure exercised on individual engineers to keep their mouths shut. They are not free. So it is toward this condition proper that most of the attention in engineering ethics is directed.

How instructive and even inspiring whistle blowing may be, arguments that situations like these exhaust the moral dimension of engineering hardly carry conviction. To force the issue: *by focussing on whistle blowing, engineering ethics evades the real problem. Within the practice of modern technology, the cases in which the four conditions for individual moral responsibility are met – if ever – are the exceptional ones.* The outcome of much sociological research in science and technology radically undermines the prevailing, commonsense conception of individual moral responsibility that also underlies engineering ethics. To make this clear, we shall go through the four conditions of moral responsibility once again.

The first condition is left untouched by science and technology studies. No one argues that engineers are out of their mind. However, science and technology studies do interfere with the remaining three conditions of moral responsibility. The second condition prescribes that the actor actually performed the action for which s/he is held accountable. In the case of engineers, the determination of this causality is not as easy as it may seem. Modern engineers are, more often than not, relatively small cogs in a large and complex machine. Therefore, when some consequences of new technologies turn out to be less desirable than expected, it is generally impossible to relate these consequences to the actions of specific engineers in a straightforward manner. As technology studies have repeatedly shown, modern technology is essentially a collective and complex enterprise. However, individual engineers are not usually only small cogs, they are also relatively powerless ones. They typically work in hierarchical organisations and have little room to follow their own choices. Thus, the third condition – about freedom to act – is not met either. Finally, the fourth condition holds that a person can only be held responsible for the consequences if those were or could have been foreseen. But science and technology studies have shown that it is hard, if not impossible, to predict with any accuracy the future consequences of new technologies for society and the environment (e.g., see Collingridge 1980).

Thus, if we follow the sociologists, the conditions for moral responsibility are seldom, if ever, met inside the modern techno-scientific enterprise. Within such an environment, it is not only hard but also often impossible to ascribe moral responsibility to individual actors. Therefore, engineering ethics is in constant danger of committing *moralism.* By this we mean the attitude of burdening individuals with moral demands and responsibilities they cannot possibly meet. There is also the connected danger of naively expecting engineers to assume their responsibility *actively*. In its passive (or retrospective) form, responsibility equals liability or accountability. On the other hand, in its active (or prospective) form, responsibility is seen as a desirable character trait, as a virtue. An actively responsible person has an acute sense of his/her duties, performs them well, and shows vision. But how strong is the motivation of an anonymous cog, without real power or foresight, to behave responsibly in this active sense? Not very strong, one would expect.

Our main contention is that engineering ethics should directly reflect the problematic status of individual moral responsibility, instead of skipping this important issue by orienting all its attention to those rare cases where most conditions for realising this moral responsibility are met. If it continues to do so, engineering ethics not only runs the risk of neglecting the major part of normal engineering practice, but also exposes itself to the associated danger of unwittingly molding situations to make them fit the contours of moral individual responsibility. The case of the Challenger disaster is a case in point here.[4] But Kline and Lynch's solution does not seem very satisfactory either. Even though they correctly chastise mainstream engineering ethics for its too-narrow focus on whistle blowing, they only focus upon the symptom. They overlook the underlying cause of this narrow focus: the desire to find situations in engineering practice that do fit the bill of individual moral responsibility with which ethicists are so comfortable. This means they stay within the bounds of mainstream engineering ethics by assuming that the use of science and technology studies will leave unscathed the core of engineering ethics, the individual conception of moral responsibility.

In the following, we shall take up the challenge of science and technology studies with regard to engineering ethics. However, we shall not argue that an individual notion of moral responsibility is obsolete, and engineering ethics along with it. Ultimately, any normative reflection on the development of modern technology has to address the responsibility of actors, i.e., individuals. Human actors can act responsibly, networks cannot.[5]

Therefore, a normative approach to science and technology cannot say goodbye to moral responsibility. But its content and its scope will have to be re-thought in the light of the findings of modern science and technology studies. We want to contribute to this re-thinking by presenting an empirical study showing the changing role of moral responsibility in a normal engineering practice. Our research for this study is based on data that were collected at our university during the 1990s (see next section).

With this study, we aim to supply evidence that the lack of incentive for moral behaviour in engineering is not a property of modern technology-in-the-making as such. It is, to a large degree, the consequence of the specific way this technology-in-the-making is organised. If this organisation is changed properly, the way moral responsibility is exercised by engineers may also change, and may become more productive. Therefore, an engineering ethics that takes the moral responsibility of engineers to heart should not omit reflection upon organisational reforms that could clear away the current impediments to practising individual moral responsibility in engineering.

## Research approach and data

We carried out our research in a number of steps that are followed through in the structure of the study presented below:

*Starting research at the level of individuals*

As we argued above, individuals have to play one role or another in the moral steering of technology. Therefore, it is legitimate to start our argument at this individual level. However, to avoid moralism, it is of the utmost importance to keep in touch with the conceptions of moral responsibility brought forward by the moral agents themselves – the engineers. They can be safely assumed to have their own ideas on responsibility – because they have the most interest in doing so. Apart from this matter of principle, there is also a more pragmatic reason to start with what individual engineers have to say. If a theoretical conception of moral responsibility is to have any chance at all of being accepted by its addressees, this conception should be developed in a dialogue with them. This is not a hollow courtesy. In a recent study, Radder has pointed out that bioengineers are highly critical of suggestions offered to them by moral philosophers for the ethical improvement of their technological practices (Radder 1996).

*Collecting and analysing empirical data*

To portray the moral agents, we sought empirical answers to the question concerning the way in which engineers themselves reflect on their responsibility as techno-scientists. Scanning the literature on ethical aspects of engineering practice delivered no systematic data about typical ways in which practising engineers think about their social responsibility. Fortunately, however, we did have access to a modest but interesting data set collected during the course of an experimental impact assessment project – called SESR, i.e., Social Effects of Scientific Research – at our university (University of Twente). This is a university consisting of a number of large technical departments on the one side, and smaller schools of philosophy, social sciences, and business on the other.

The SESR project started in 1989 and continued on through the 1990s. Its objective was to develop measures for stimulating discussion about the social effects of technical research – either planned or already in progress – at our university. The SESR project was initiated in reaction to the conclusion of a highly controversial research contract between a research group in the Technical Physics Department and Urenco, a nearby uranium-enrichment facility. Through this contract, the university became linked to applied research in laser enrichment of uranium in a business context. Particularly the potential military applications of this kind of research triggered excitement about this contract in the university community and in the local press. This excitement can be understood from the fact that, at the beginning of the 1970s, the university had declared – by a decision of the Board – that it would not engage in research with military applications. To neutralise the controversy resulting from the Urenco contract, the Board of the University launched the SESR project (see Jelsma and Van de Poel 1992). In the framework of this project, scientists in the technical departments (mostly engineers) were interviewed about their views on the social responsibility of practitioners. These interviews are the primary source of data for our research.

Typical statements by the interviewees are presented in the first part of the study. This is done by arranging these statements according to the four conditions of moral responsibility as spelled out in the introduction. In the second part, we critically appraise the engineers' opinions against the same conditions, and we question the tenability of these conditions in the context of a modern academic research setting.

*Extending the scope of research beyond the individual level*

The inclusion of societal criteria in matters concerning the funding of university research programs – one of the measures resulting from the SESR project – opened the opportunity to investigate whether these criteria influenced the way in which questions of societal responsibility were handled and research decisions were made. We studied this aspect at the research-team level, and report on it in the third part, in a concise case study on the choices made within a research project on biodegradable plastics within our university. We derived the data for this study from an investigation carried out by one of our graduate students (Schaareman 1997). This investigation is based on in-depth interviews with technical scientists involved in the project, especially the project leader and the Ph.D. student who carried out the research.

*Connecting the individual and institutional level*

In the final section, we connect both levels of moral action in terms of an incentive structure at the university level, setting the stage for the moral agency of individual scientists.

## Interviews with engineers about their responsibility as technical scientists

In presenting the interview results, we shall leave aside the rather trivial first condition for moral responsibility, i.e., rationality, for the simple reason that it is never seen as a problem in the case of engineers. Thus, to be attributed moral responsibility or to accept it, the three remaining conditions are:

A the actor has to have acted, s/he had to be the *cause* of the consequences;
B s/he has to have acted *freely* and *willingly*; and
C s/he has to have done so *knowingly* – both with reference to the relevant facts of the case and with reference to the relevant norms and values. The engineer should at least have been in the position to acquire sufficient knowledge about the consequences of his/her professional actions and their (un)desirability to make responsible actions possible.

To what degree do engineers themselves feel that these three conditions are fulfilled in their own daily practice? For answers to this question, we shall turn to the interviews.

### *A. Actors and causality*

Although, at first sight, it may seem a fairly straightforward matter, the causality between actors and actions is often difficult to establish in the reality of modern technology development. Not only do we find ourselves confronted with the so-called problem of "many hands", but more often than not, the causal chain between action and consequence is hard to establish. One reason has been mentioned already: the fact that modern technology development is a multi-actor enterprise. But our respondents frequently pointed to another, albeit related, reason. In the case of technology, there is inevitably a gap between the designer and the user of technology. Our respondents repeatedly referred to this gap. In their view, they hardly "do" anything when it comes to the implementation of their research results. That's all other people's work: "one cannot prevent improper use of one's results". Engineers only come up with the instruments, others are responsible for the consequences of their use. This is one important reason for the engineers' belief that their individual responsibility for the possibly negative societal consequences of their work is severely restricted.

However, exceptions to this view were reported. Some respondents did feel that, in their line of research, it is quite possible to foresee how the outcomes of their work will be used: "Everyone who does not live in an ivory tower knows what use society will make of his work". And as soon as a designer is aware of what future use will be made of his or her instruments, s/he is co-responsible for this use to a certain degree. This view seems to correspond to commonsense notions of responsibility: if I give a gun to a known killer, I am co-responsible if s/he goes out to kill someone with it. Interestingly enough, this is not the reason why some respondents are quite clear about their refusal to work for the military, or why several other respondents said they try to steer away from controversial research. On the contrary, this notion of co-responsibility is most often put forward in those cases where the respondents feel the uses of their technologies are beneficial. Most technological designs are developed with such beneficial goals in mind, and engineers are keen to accept co-responsibility for these.

### *B. Freedom of design and of research into the consequences of the design*

In the case of technology development, there can be more or less freedom to perform two basic kinds of activity: (1) design work proper and (2) research into the possible consequences if these technological designs become implemented. Thus, in discussing the moral responsibility of engineers, we have to distinguish between these two levels of freedom.

1 According to our respondents, their freedom to design what they want is limited. The reason for this is that they feel forced to seek collaboration with business organisations and therefore to submit themselves, to a certain degree, to commercial incentives and to the necessity to compete with market parties. Although they feel market orientation curtails their academic freedom, they still seek collaboration with parties closer to the market for three main reasons. The first reason is economic: business provides the funds necessary to do research. But they also come up with less down-to-earth reasons. Universities are not the only knowledge institutions in modern society. Firms have vast research facilities, and the knowledge produced there is often only

accessible to academics through collaboration: "[by collaborating] you get access to confidential information about what these companies are working on". Enhancing the practical relevance of academic research is a third goal that counts in the collaboration with business organisations: "It is a matter of mutual interest that universities, which are objective, and industry, which is close to practical problems, collaborate. If not, you get irrelevant universities and impractical standards". Several respondents made it clear that they regard an enlargement of the probability that their ideas will be put into practice as a substantial advantage of collaborating with business.

However, the perception of these advantages does not mean that our respondents close their eyes to the potential reverse side of this coin. Collaboration with business may be inevitable because of the benefits it offers, but this does not mean that there are no costs. Two kinds of costs were repeatedly mentioned. First, the need to collaborate decreases one's scope for adopting a principled, moral stance in those cases calling for such a stance: "There is an increasing need for funds from outside the university. And then discussions become more difficult. The need for money leaves little room for principles". Another respondent remarked that he would "lose his credit with external financiers, and put an end to the collaboration" if he were to take a critical stance. Second, to our respondents, the main criterion for success still remained scientific relevance: "going purely for the money is despicable". However, they saw this kind of scientific attitude as being different from the primary motivations of their business partners.

2 How free do our respondents feel to invest time and money in finding out about the future social and environmental consequences of their technological innovations? Most respondents made it abundantly clear that neither the university nor their business partners appeared to be much interested in early assessments of the possible adverse consequences of their research activities. Many of the respondents believed that the university's lack of interest in this matter is shown by the fact that it primarily pushes its employees toward scientifically relevant output. As one respondent told us: "We work hard on the technical side, but not on the social one. That should be taken up by the university, but not by our department. We are already forced to swim very hard to keep ourselves from drowning. In that respect, the world is very hard and simple". This is not to say that our respondents made the general impression of suffering severely from this lack of stimulation. One characteristic quote illustrates this as follows: "It will be very difficult to make funds available [for looking into the consequences]. We have different priorities within our department. Education and research are in a tight spot as it is. And we do not

want regulations and facilities at university level because, in the end, that only swallows up the scarce funds".

We conclude that the freedom of these engineer-designers is restricted on two levels. First, they feel forced by financial and professional reasons to enter into collaboration with business partners, restricting the possible avenues for inquiry. Second, neither these business partners nor their direct employer is perceived as being much interested in impact assessment along moral standards. Both push the engineer-designer in directions deemed commercially and/or scientifically important. But it is not only a matter of pragmatic reasons, i.e., funds and time, that discourages respondents from investing in impact assessment. There are also more substantive arguments why they do not systematically investigate the possible ethical, societal, and environmental consequences of their technological work. This leads us to the third condition.

### *C. Knowledge of the consequences*

Basically, the respondents came up with five more fundamental reasons why they cannot collect valid knowledge about the consequences of their work. First, the possible consequences of newly implemented technologies are too manifold, too complex to be foreseen with any acceptable degree of certainty: "Everything we do has social consequences". Second, these consequences often take too much time to manifest themselves: "It is a major problem that, in the long run, these consequences are unpredictable". Third, more often than not, desirable consequences are intrinsically linked to less desirable ones. If you want the one kind, you simply have to accept the other: "Even if there were military uses, I would not stop my research because it will simultaneously yield results that are crucially important for the medical sector". Fourth – and this is perhaps the most basic reason – it is, by definition, not the technology developer who determines what the consequences will be, but the user of the technology: "Yes, there are unintended consequences. But these do not have much to do with the technology. You cannot influence them. After twenty-five years, I still cannot fathom how the medical sector works. If we come up with a cheaper technique, the result often is that the total costs go up because this technique is more often employed than before, and the physicians can write out bills each time". We have seen this type of argument before, in a slightly different context. There the argument was that "user autonomy" washes out the causality of those who designed the instruments and the consequences of use. Here the point is different: "user autonomy" means that the consequences of a new technique cannot be adequately known beforehand.

Finally, the normative evaluation of probable consequences is said to remain inevitably a matter of subjective taste: "What is deemed socially relevant is also a matter of your political stance".

### Critical evaluation of the interview data

Which notion of moral responsibility issues from these deliberations by the engineers themselves on the three basic conditions: causality, freedom to act, and knowledge about the consequences? Let us take the three conditions one at a time. We shall see that there is much that is convincing and that should be taken into account to avoid moralism, as defined above. But there are also some points that are less convincing, and some inconsistencies that should make us stop in our tracks.

*re A* Reflecting on their remarks about causality, we see the interviewees hiding behind their academic freedom when denying their responsibility for unforeseen negative consequences: *they* did not do anything possibly contentious, the users are responsible. But when the technology turns out well, they are the first to claim responsibility. Nevertheless, there is considerable truth in these claims about causality (or lack of). However, this is not the whole story. Whether an engineer can be considered as a moral actor, i.e., whether s/he can be held responsible for the use made of his or her designs, depends to a large extent on the knowledge variable (that is condition B): could s/he have foreseen these uses and therefore (some of) the consequences of the technology s/he designed? In the interviews, respondents offered both pragmatic and fundamental reasons for not being able to assess these uses and consequences: no time and no money, and they even called this type of foresight essentially impossible. In appraisal of this pragmatic argument, we can say that it covers up the choice that is involved here: time and funds could, in principle, have been used differently. With reference to the second, more fundamental argument, it has been observed that, although it may indeed be impossible to foresee all the consequences of a technological design, at least some of these consequences can be anticipated. This is all the more so because a technological artifact has a "script" (Akrich and Latour 1992), i.e., it prescribes to some extent the uses that will be made of it. It should be noted that, even if this specific feature of technological artifacts has now been sufficiently established by the critics of the instrumentalist vision of technology, this vision remains dominant among engineers.

*re B* Concentrating on their remarks about their own freedom of action, we find that the engineers themselves point out what sociologists call "the network character" of technology development. According to that conception, individual engineers have a very restricted moral agency. Their practical options are severely limited by the fact that technology development is not a matter of isolated individuals, but is essentially a complex, collective affair of actors with conflicting agendas.

However, if we look a bit closer, there is something peculiar about the way respondents describe the restrictions they feel bounded by. The restrictions of their freedom to act within this network prove not to be a completely fixed matter. Instead, these restrictions seem to be subject to negotiations, and to have a gradual character. This gradual character becomes clear in remarks like: "*We only seek collaboration with business organisations on the condition that this results in work that is scientifically relevant*". Thus, a rather remarkable inconsistency seems to exist here. On the one hand, engineers refer to the network character of modern technology development to deny moral responsibility for their actions. On the other hand, these same restrictions are not deemed compelling enough to overrule the classic and fundamental demand of scientific relevance. Why then would it not be possible to refuse that same collaboration if other, moral, demands would require this?

This inconsistency, however, can be explained in a sociological way, i.e., by leaving the perspective of the actor and invoking structural factors that shape engineering practice. In that perspective, it is easy to see that respondents are part of two networks: they are part of a network in which business organisations play a major role. But they are also, and probably more fundamentally, part of an academic network. In this latter network, their failure or success is rated according to their scientific prestige, and hardly at all in terms of the possible ethical content of their work – all the more so if that content is not manifest at first sight.

*re C* Concerning the question to what degree, if at all, the future consequences of new technologies can be predicted, we have seen how respondents came up with five fundamental reasons why this is not the case or, at best, is only the case to a very limited degree. Some of these reasons, however, are more convincing than others. For example, the last argument – that any evaluation of these consequences will be subjective and contested – may be nothing more than an old positivistic reflex: we can agree on hard facts, but not on soft values. Be that as it may, this argument does not really contest that the consequences themselves can in principle be foreseen, only that their desirability may be a matter of subjective taste or political debate. The same holds for the argument that good and bad are sometimes inextricably entwined. This is undoubtedly true, but it does not follow that these intricacies cannot or should not be made visible in advance. So this leaves us with the other three reasons why, according to the respondents, it is often impossible to predict the probable consequences of new technologies: they are too complicated, are too long-term, and are independent of the intentions of the designer and are dependent on the future user.

Although we accept that there is considerable truth in these objections, we do wish to point out a rather striking discrepancy between the respondents' modesty when it comes to predicting risks on the one hand, and their willingness to accept credit for success on the other. One plausible way of interpreting this inconsistency is by pointing to the self-interest of our respondents. They seem to manoeuvre for maximum autonomy combined with minimum responsibility. They achieve this feat by alternating between the abovementioned restrictions if someone appeals to their moral responsibility, and referring to their academic freedom when negotiating with business.

## A brief case study: Designing biodegradable plastics

In this section, we describe the case of a technical design process that is relevant because of the attention given to moral aspects in the course of the design activities.

At the end of the 1960s, a new research group (Biomedical Materials) was established within the Department of Macromolecular Chemistry at Twente Technical University. The research topic of the new group was the design and development of biodegradable polymer materials for medical use, e.g., ligature threads and capsules for the delivery of drugs in the body. Such materials have to meet conditions of controlled degradation. That is, they must have vanished from the body within a fixed time span and should not leave health-damaging debris. The latter objective can be realised by taking natural substances such as lactic and amino acids as a starting point for the design of these medical products.

In contrast to the polymer chains applied in medicine, another polymer material started to stir social concern in the 1970s. Specific synthetic substances ("plastics") widely in use for a range of applications, especially as packing material, had become a major pollution problem. Being non-biodegradable, they popped up everywhere in the environment as persistent waste. Entrepreneurial scientists scented a market for biodegradable plastics. However, the first attempts to develop such plastics from blends of starch (a natural polymer) and polypropylene were not very promising. Now and then, the scientists at UT played with the idea of searching for something better by building on their expertise with biomedical materials, since these materials were completely biodegradable. The apparent societal need for biodegradables might help to acquire the funding needed for additional research. What held them back for a long time was the difference in markets. Medical biopolymer products were technically sophisticated, expensive, and were sold in niche markets at high prices. A biodegradable substance appropriate for use in all kind of packages had to be some kind of cheap bulk material intended for a mass market. The biomedical materials were simply too expensive for this kind of application. For that reason, the scientists in Twente did not take action, but kept an eye on developments.

In 1989, the visit to a scientific conference where "biodegradable materials for the environment" were high on the agenda set the ball rolling. The research group decided to undertake a serious research effort into the development of a biodegradable plastic for bulk application. Since a study of this kind of material did not fit into the regular research program, its development had to be funded by external sponsors. Informal contacts that the group maintained with industry indicated that polyethylene-terephthalate (PET) was a promising candidate as a "raw" material. PET already contains degradable bonds, but degrades very slowly since it is very hydrophobic. By building an easily hydrolizable substance into the PET chain, the UT scientists hoped to lower the hydrophobia and to increase the biodegradability of PET. A quick survey of the literature taught the research team that several substances might prove appropriate, and that there were no patents excluding collaboration with a partner in industry. In 1992, two team members visited a large chemical corporation that was known for researching PET. But for a number of reasons, this firm was not interested in supporting the UT team's efforts to make PET biodegradable. Thus, funding had to be sought elsewhere. Six months later, the "Polymer products and waste management program" (POWAM) offered a new opportunity.

POWAM, established in 1992, was a multidisciplinary program for environmental research funded by the UT itself. Its objective was "to contribute to possible solutions for the urgent environmental problems stemming from the societal use of synthetic polymers". Funding by POWAM meant that a research team had to undertake a critical assessment of the technological, societal and political implications of the polymers to be developed. This condition stemmed directly from the SESR policy developed by the Board of the University (see above), now implemented through research programs such as POWAM. The research group within Biomedical Materials successfully applied for POWAM funding on behalf of a project called "Biodegradable Polymers to Reduce Polymer Waste", which was started in the spring of 1993. The basic idea of this project – modifying PET to turn it into a biodegradable substance – remained unchanged. However, the obligatory societal assessment which was carried out after the first research year yielded an unexpected outcome. The assumption about the environmental need for a biodegradable plastic, on which the project had been built from the beginning, appeared to be largely unfounded. In the policy-oriented literature, biodegradable plastics were juxtaposed with more sustainable alternatives such as recycling or re-use of packages. To be socially viable, biodegradable plastics would at least have to prove their superiority over these alternatives in comparisons based on robust environmental assessments such as life cycle analysis (LCA). In the Dutch National Policy Plans for the Environment (*Nationale Milieubeleidsplannen, NMPS*), biodegradable plastics were not even mentioned as an option for alleviating waste problems. These outcomes came more or less as a shock to the researchers involved with PET. They had always perceived biodegradable plastics as a technical solution with a promise embraced by society. Now it became gradually clear to them that they had only been cherishing a vague dream of their own. To come true, this dream had to fit credibly into a developing picture of sustainable waste policy and, to realise this fit, the technical design needed a convincing story and the right performance.

Arguments underpinning and articulating the promise of PET were developed in a book about POWAM (Smits 1996). In an article about the role of polymers in waste management, the PET researchers carved out a niche for their emerging product by recommending its use in applications ending in waste streams that are hard to recycle, such as those produced by households. After biodegradation, the remainder of such waste can be re-used as biomass or, if degraded anaerobically, as methane. If natural substances can be built into biodegradable polymer products, a neutral $CO_2$ balance is within reach. The authors coined the term "biological recyclability" for this kind of opportunity. Further, they sketched a scenario to underpin the economic viability of large-scale use of biodegradable synthetic polymers in society. According to the authors, this viability presupposes a world in which (i) exhaustion of supplies has driven up oil prices sharply, (ii) the price of biodegradable synthetics has fallen considerably due to increase in scale, (iii) the imposition of taxes on waste favours the use of bio-recyclable products, and (iv) the presence of an adequate infrastructure enables the collection and processing of organic waste. The authors admitted that to acquire a precise picture of the contribution to the alleviation of waste problems, their option of biodegradable polymers had to be tested against alternative solutions by carrying out

LCAS (Stapert et al. 1996). The POWAM book was presented at a UT workshop ("Plastic Waste: A Technical or a Societal Problem?") which was part of a series of SESR workshops.

In a presentation to a UT conference ("The Moral Script in Technical Design") during the following year (1996), an effort was made to connect the PET project more closely with Dutch waste policy. The researchers agreed that, as this policy stipulates, prevention and re-use of waste are the most desirable options. For the remainder of the waste, the concept of biological recycling had now been further articulated by comparing it with chemical and mechanical recycling. The latter approaches both presuppose separation and collection of different types of waste before recycling can occur. But biodegradable polymers, so the researchers stressed, need no separation from the rest of the organic waste – such as that produced by households – before it can be processed into compost. Another aspect of the societal embedding of biodegradable plastics was their manufacturability. According to the PET engineers, the development of synthetic biodegradables should form the beginning of a technological trajectory which may shift to the more favourable natural (i.e., renewable) polymers in later stages. They perceived commencement with natural polymers as impossible, because processing these substances is too remote from current expertise and practice in the chemical industry.

An explicit design constraint resulting from the societal assessment of the project was "compostability", i.e., the biodegradable plastics must be degradable into compost. Biodegradable plastics can be conceived as artifacts with competing action programs. On the one hand, these plastics must be sturdy for use as bags, covers, etc., whereas, on the other hand, they should quickly weaken and disintegrate when discarded. The composting process can link both programs by offering an accelerated breakdown of materials robust enough for practical use as plastics. Moreover, compostability was required to embed plastics in emerging regimes of processing organic household waste in Dutch cities. These regimes produced compost as an end product. Both considerations meant that the compostability of the biodegradable plastics under development had to be tested. This demand required an extension of the design process by the development of a definition of compostability and the development of a standardised test methodology. These requirements were realised by means of collaboration with a research institute at Wageningen Agricultural University. In 1995, the partners concluded a contract by which Wageningen University committed itself to carrying out biodegradability tests in exchange for support of the Ph.D. fellow in charge by the head of the Biomedical Materials research group at the University of Twente.

### Evaluation of the case study

As with the interview data, we evaluated the case study against the chosen preconditions for the attribution of ethical behaviour.

#### *A. Actorship and causality*

What kind of actions did the engineers carry out within the practice of the project studied? These actions can be described in different ways. To begin with, our chemical engineers attempted to synthesize new substances called "biodegradable plastics". As we showed, such substances have two contradictory action programs, like safety belts and airbags in cars (Latour 1992). Creating this kind of dual substance is a complicated task requiring sophisticated knowledge, experience, skills, tools and resources, a kind of heterogeneous and connecting activity we call pure science.

At the same time, we can describe the actions of our engineers as entrepreneurial. What they do is attempt to make the knowledge and expertise of their department – biopolymers for medical use – work in the new domain of environmental technology. That is, they want to conquer new territory with new ideas and new products and, in doing so, add value to the investments they have already made.

Furthermore, our engineers hope to build a better society by means of their professional activity. In this sense, there is also a moral incentive behind their activities. By advertising their project, they seem to indicate some kind of responsibility for the unwanted effects of previous endeavours by chemical engineers, that is, the construction of *non*-degradable plastics, which have become an environmental nuisance. At this point, we should realise that it is quite possible, even probable, that this responsibility for the waste problem is more easily assumed if the development of a technical solution to that problem can be turned into a promising new project from which benefits can accrue. In this sense, some of the opportunism we noticed earlier in the interviews may become manifest here too.

Having discussed the actions, we turn to the causality. In the interviews, the engineers expressed ambivalence on this point. They considered it rather unpredictable which use "society" might make of research outcomes, but not completely unpredictable. In an earlier section, we speculated that this ambiguity has to do with the networks in which the engineers participate in order to realise their designs; that is, to figure them out, to articulate and develop them, and to make them work. Thus, the engineers construct causality themselves, but they are not the only constructors. Their actions are shaped and framed by, and attuned to, those of other actors with whom they share networks of collaboration. Indeed, the making of modern technology is a very specialised, multi-actor undertaking (Rip et al. 1995; Rip and Kemp 1998). The current idea among sociologists of technology is that different collectives of actors participating in the development of a specific piece or field of technology are linked up by an "innovation chain" or rather – to borrow a more dynamic and iterative concept – by "techno-economic networks" (Callon et al. 1992). Such networks link activities in science, industry and the market. It is a major goal of modern technology policy to construct such networks, or to close the gaps in them. Causality develops gradually in such networks, while none of the actors is in full control of this development (Elzen et al. 1996).

When we look at the practice as revealed by the case study, it becomes clear how the actions of the engineers acquire a sense of direction. The network(s) in which they operate function(s) as incentive structures shaping their actions and giving them significance in both a cognitive and a social sense. Within the science pole of the network in which our engineers work, the ruling paradigm inspires the course of action in making the new artifacts, i.e., the chemical substances called "biodegradable plastics". The main direction is clear – combine aliphatic hydrophilic carbohydrates with hydrophobic aromatic ones in a polyester molecule to realise the dual "action program" of the molecule. The precise composition of the chain has to be discovered: which groups should be linked, what length the chain should have. That is what most of the experimentation, i.e., the engineering action, is about. To determine these details, the engineers derive ideas from their own experience, from their colleagues within the research team and those they meet at conferences, and from the scientific literature. In other words, they tap the science (part of the) network. But they know that to make their molecules work in society, these have to be processed into products on a mass scale. It is quite clear that they lack the resources and skills to do that themselves. In fact, they have no equipment to test their molecules for this purpose. Therefore, actors in industry are needed – another (part of the) network. To interest these actors and to link them to their project, the molecules in question have to meet certain requirements. Our engineers assume that they have to offer a substance that is easy and cheap to produce on a large scale, a bulk product, otherwise their molecule will have no chance. This also requires research effort because the biomedical polymers with which they are familiar are expensive and can only be sold in niche markets (hospitals). Further beyond, that is, beyond industry and its supposed demands, there lies a "society" in which the biodegradable molecules might eventually be used. Our engineers have the idea that their molecules hold a promise for solving, or at least mitigating, the waste problem that "society" is wrestling with, but this idea is only a very vague one. It is based on a very general and unchecked scenario announcing that waste problems due to plastics will aggravate to the extent that "society" will embrace any biodegradable plastic as soon as it can be produced.

Thus, there is a sense of causality in making biodegradable plastic right from the beginning. This is inevitable, of course, otherwise there would be no project. However, the more the distance from the science pole – the workplace of our engineers – increases, the more the articulation of this causality declines. Our engineers are quite capable of explaining in detail those molecules that will probably work in "technical" terms. However, with regard to the question as to how such molecules will be adopted into society and how they will work in "social" terms, the engineers only have vague answers. In the interviews, there was some speculation about the reason for such difference in articulation, in the sense that the structure at the science pole lacks incentives to elaborate the "social side". Indeed, the case study makes clear that the primary concerns of the engineers are the originality of their findings and the possibility of protecting them by a patent. In the next sections, we shall see that as soon as the incentive structure becomes more rewarding in this respect, investments will be made to also cover the "social" part of the venture, with stunning outcomes.

### *B. Freedom of design and the societal effects of research*

In the interviews, the engineers emphasised that the financial need to collaborate with industry constitutes a severe limitation of their academic freedom: "*the need for money leaves little room for principles*". This quote suggests that industry more or less dictates the kind of research that academic research teams should perform. Our case study did not confirm this situation. It is rather the other way around, in the sense that our researchers tried (in vain) to enroll firms in an academic project. The mainsprings of this initiative were entrepreneurial incentives mixed with some principles, and encouragement from the outcome of a feasibility study allied to some initial interest from the side of industry. The case study alone does not prove, of course, that this kind of development pattern is a general one, but it does suggest that the statements on this point in the interviews are questionable.[6]

The second aspect of freedom we distinguished is the freedom to investigate the societal effects of the research being carried out; that is, to undertake efforts directed at impact assessment. In the interviews, the engineers provided strong opinions about this point: the research context does not welcome, let alone reward, the assumption of a moral stance on a project. Consequently, there is a lack of incentives and resources for activities aiming at impact assessment. This situation is taken as the reason why engineers "*work hard on the technical side [of a research project], but not on the social side*".

Such opinions can primarily be explained from the engineers' entrepreneurial role. The case study shows that, to keep the project alive, the engineers have to sell it to sponsors. In this pursuit of resources, the natural tendency is to emphasise the promise of biodegradable polymers. Falsifying this promise, i.e., inquiring into the "negative social consequences" of these polymers, would be counterproductive. In addition, the engineers' distinction in the project between the "technical" and "social" aspects of their work on biodegradables is remarkable. This kind of duality in their discourse seems to indicate that they may not be aware of the fact that their technical activities shape a social reality through a developing causality as sketched above. That is, they help to create a society in which biodegradability makes the use and the jettisoning of plastics on a massive scale even more attractive. Another possibility is that polymer engineers are more or less aware of this, but their opinions refer to a difference in degree of articulation regarding the various kinds of research activities, as we explained earlier. That is, research on matters of societal impact (how the desirability of biodegradable plastics precisely relates to existing priorities in waste policy, etc.) suffers from a lack of attention and resources, compared with molecular research itself, and therefore these matters remain vague. The concern about such societal questions is delegated to industry, which is "closer to the practical problems". Our engineers seem to have a division of labour in mind: we deliver a cheap bulk polymer, they dream up the applications for they know the market! This is indeed a division of labour leaving our engineers a maximum of room to manoeuvre.

The establishment of the university-sponsored POWAM program changed this incentive structure significantly. In the framework of this program, the polymer engineers were seriously engaged in impact assessment, since the program required this as one of the conditions of receiving funds. Now they have to elaborate their vague scenario of future developments in societal waste management. In the effort to articulate their ideas, they discovered that the world outside academia is different from what they thought.

### *C. Knowledge about the societal effects*

Again referring to the interviews, we recall that the engineers interviewed mentioned five reasons that more or less made the exploration of the consequences of their design work impossible. On the basis of these data, we might expect the engineers to protest against the impossible task placed on their shoulders by the POWAM program requirement to assess the societal consequences of their technical project on degradable polymers. Strangely enough, they do not protest. Within the practice of the POWAM project, the engineers dug into the future quite zealously instead of sitting back and complaining about the complexities of the "social" world. On the one hand, they forecasted a world in which their biodegradable polymer would find a niche and would have opportunities. In this scenario, the engineers do not shrink back from predicting the development of different kinds of socio-economic factors in the long term, from oil supplies to green taxes. They also mapped out a technological route within which the development of biodegradable plastics could be imagined to take place, and they emphasised the advantages of biological recycling (i.e., not requiring separation of waste) compared with the alternatives of the moment, i.e., chemical and mechanical recycling, that rank higher in political terms. The consequence of this scenario is that biodegradable plastics should be compostable, that is, the design requirements changed. As a consequence, the network around the project had to expand to include partners (found at Wageningen University) able to realise this societal inscription in the molecule.

In other words, our engineers do not try to predict the manifold and long-term consequences of their technology, i.e., of the molecules they had constructed. This would indeed be an impossible task. Instead, they develop an educated forecast of the social world that the technical concept of biodegradable plastic is expected to meet, and they adapt the molecular design accordingly. Thus they do not sit passively, simply leaving the fate of their molecules to unpredictable "users" in society. Which means that our engineers are not only acting as technical engineers "only constructing molecules", but they are also acting as *social* engineers.

## Discussion and conclusions

In the interviews we have analysed, scientists refer to constraining structural factors as a primary cause for the lack of agency they experience in matters of social responsibility related to their research. That is, our scientists do not consider themselves as autonomous seekers of truth. In morally accounting for their actions as researchers, they rather take their environment as a reference. The way in which they describe the restrictions they experience in behaving responsibly comes close to the picture that modern sociology of science draws of the modern scientist, namely, as an actor whose agency is enabled *and* constrained by structure, i.e., by the technical frames (Bijker 1995[a]) and the networks s/he needs for the "co-production" (Rip et al. 1995), "realisation" (Radder 1996) or "construction" of techno-scientific (arti)facts (Latour and Woolgar 1979). In the relationships referred to by the scientists interviewed, commercial sponsors appear as the dominant actors to be taken into account, with users being regarded as determining the final effects of technical designs. It is remarkable that the interviewees apparently perceive these actors, especially the users, as being much more autonomous in their actions – that is, less constrained by structure – than they themselves in their role as scientists. Consequently, they attribute to these actors more responsibility for the impact of technology than they are willing to take themselves.

Though it is clear that research is to be carried out in an "impure" world where the scientist has to keep the low company of commercial interests, our interviewees stick to formulating their mission as "pure research". A kind of purification seems to be going on here enabling the immaculate scientist to make the vulgar allies responsible as soon as the outcomes of joint efforts become a social problem. As to becoming knowledgeable about the societal effects of their professional activities, the engineers feel equally constrained. The character of the restrictions they mention corresponds closely with the outcomes of analyses made in the field of technology studies, such as the recognition of a *control dilemma* inherent in the assessment of social effects of technology (see e.g., Collingridge 1980). Moreover, as far as these effects can be assessed at an early stage, the interviewees perceive no incentives spurring them to do so within their professional academic environment. The engineers interviewed meet the issue of their social responsibility with a mixture of fatalism and opportunism. Their argument on which this attitude rests can be summarised as follows: *in our professional environment, the structural conditions to behave responsibly are not fulfilled, so we cannot be moral actors. Where things go wrong, we cannot be held accountable.*

We appreciate the engineers' account as an adequate assessment of the moral position of today's *individual* scientist. It leads us to the conclusion that the three basic preconditions for the attribution of moral responsibility do not apply in the situation of the present-day individual scientist. To force such responsibility on these scientists individually would indeed lead to moralism. However, by accepting this conclusion, the engineers would escape too easily. When we look through the lens of the case study at the actual behaviour of the scientists, they do not appear quite so helpless. In developing biodegradable polymers, the engineers do not seem to play their modern role as entrepreneurial co-producers of technology in a reluctant manner. On the contrary, they tend to play it actively and emphatically. Indeed, this means that they are not individual truth seekers but dedicated team workers and network builders. This is the very role that society expects nowadays from, and attributes to, the workers at the science pole of the modern "knowledge infrastructure". In fact, playing the entrepreneurial role well could be conceived as a major characteristic of the societal responsibility of the modern scientist.[7] Knowledge workers at the science pole are supposed to come up with a constant stream of new ideas and to make these ideas work by inscribing them into hardware (in our case, into specific molecules), by attracting funds, and by building new alliances. However, in order to create any room to manoeuvre and to raise funds, the inscriptions to be made should have at least some credibility of future pay-off for both the scientists themselves and for other investors. For that reason, a narrative is developed that includes promises about and forecasts of future effects – such as "reducing the waste problem" – to be realised by the new (but still fictive) molecules. Such promises and forecasts build a "prospective structure" guiding further action and resource building (Van Lente and Rip 1998). Thus, despite the fact that anticipations of societal effects are qualified as inherently difficult if not impossible in the interviews, the scientists do speak out about such effects as a precondition for creating this kind of prospective structure. However, the social effects suggested as issuing from the new research path of biodegradable plastics are very imprecise. Moreover, these promises are constructed in a narrow setting (the science pole), and their reliability is not checked against the wisdom of external experts by broadening the network towards relevant policy circles. In other words, politics *within* science (the technical inscriptions made in conjunction with the local narrative justifying these inscriptions) is disconnected from the wider *societal* politics. We suppose that this is the normal way of shaping social responsibility as it occurs in modern scientific practice, but it is a rather narrow-minded and not very productive one. For as long as the moral promises and forecasts about desirable social effects of research conceived at the science pole are not embedded in the views and actions of other actors crucial for "realisation" or "co-production" – i.e., as long as they are kept "pure" – they will never fulfil their sweet-sounding prophecies.

Appraising the tension between what our chemical engineers say and what they do, we might conclude that they are trapped in the duality of structure (Giddens 1984). The very structures they build and reify as a frame for their entrepreneurial agency are experienced by these same scientists as given constraints shackling their social responsibility. Because of this hidden duality, the science pole seems to (dis)function as a morally unreflective, reproductive Boudonian system lacking feedback from its environment. Such systems can begin to learn and to transform when they start to generate a certain level of aggression in their environment (Boudon 1974).

The establishment of a collaborative agreement between the research group of the Technical Physics Department and Urenco (see section 2) did trigger such aggression. The Department, and the Board of the University in its wake, came under moral pressure to re-assess research goals because of the possibly unwanted societal effects (military applications of laser enrichment of uranium). The change of institutional rules for internal funding of research projects resulting from this clash created an incentive structure more favourable to moral agency at the research team level. The addition of a societal assessment clause to project funding conditions had a profound influence on the further development of the polymer project at the network building level as well as with regard to the technical content of the project. After a serious exploration of Dutch waste policy in relation to the idea of making plastics biodegradable, the rationale of the project became much more articulated and changed considerably, as appears from the article in the book about POWAM. Accordingly, the project was steered away from mere biodegradability towards compostability of plastics, an aim which fitted much better into current waste policy. In turn, this socio-technical change required changes in network building around the project. The research team no longer aimed at establishing relations with large firms to develop a bulk product, but became interested in small firms exploring niche markets for compostable plastic products like waste bags instead. To test the compostability of the prototypes of the molecules designed, the team initiated collaboration with a research group at another university. In other words, *due to the change in rules, the science pole started to be more sensitive to its environment, became morally reflexive about its research aims and about the resulting molecular inscriptions, and recruited different allies.* Moreover, it articulated a much more realistic scenario about the future world in which its research product would function – i.e., more in agreement with the agendas of crucial partners for further development – than before. Finally, politics within science became connected and attuned to wider societal politics.

Though the perceptions and concerns of practitioners with regard to the bounds of modern technoscience enterprise should be taken seriously, they do not force us to conclude that we should dismiss the notion of the engineer's individual moral responsibility. Rather, a sociologically informed way of studying engineering practice helps to reveal the particular moments and particular characteristics of practice at which and by which the conditions to execute this individual responsibility are favourable or limiting. We have tentatively demonstrated this by examining the normal practice of engineers in an analysis of their perceptions as made clear in interviews, and in an investigation of their real actions in a case study. The outcome of this analysis is that engineers simultaneously strategically operate within *and* refer to the structural (i.e., network-like) character of their practice as a ground for shifting moral responsibility to others. Our own conclusion is different; namely, that recognition of this structural character opens new options for agency regarding the responsibility of engineers.

At the same time, we do not deny that, for individual engineers, it is difficult to realise these options on their own. The POWAM experience shows that to create incentives for engineers to assume social responsibility, the individual engineer level has to be transcended, and initiatives for policy making have to be taken at the institutional and societal level. Thus, reflection and research on how engineers can contribute to the shaping of institutions, procedures and instruments that allow the social assessment of specific design activities, and the democratic deliberation upon these, should be part and parcel of engineering ethics. On the institutional level at the science pole (the part of techno-economic networks that is the focus of our analysis), one could imagine initiatives to be taken such as:

- creating funds at the university or faculty level for the assessment of projects expected to have considerable and/or ambivalent societal impact
- developing best practice methodologies for supporting engineering scientists in carrying out such assessments at the research team level (Jelsma and Van de Poel 1992)
- evaluating experiences with assessment practice at the faculty level from time to time
- striving for diversity and richness of networks around design projects.[8]

Further suggestions can be found in the literature about constructive and interactive forms of technology assessment (Rip et al. 1995). For research teams in industry, suggestions for impact analysis and tools for network management and social learning have been described by Deuten et al. (1997). Project managers directing radical innovations can turn to the Socrobust approach for help in revealing the kinds of social environment presupposed by such innovations (Larédo et al. 2002). Further steps taken to enhance the social accountability of firms could provide leverage at the research team level at the science pole, too, but discussing such mechanisms is beyond the scope of this study. With respect to any such assessment initiatives taken, it is important to stress that they should not be restricted to the societal impact of technical design projects but should also include the contingent framing of the design activity within networks and their related issues such as access, openness, diversity, ownership, etc.

The foregoing considerations lead us to the following conclusions. First, structural conditions for taking individual moral responsibility in the normal practice of engineering at the science pole can be developed and realised, but engineering ethicists pay little attention to this course of action because of their pre-occupation with exceptional cases, i.e., cases of whistle blowing. Second, such structural conditions can only be created by initiatives at higher structural levels, that is, above the work floor of engineering where practising engineers are not the primary actors. However, this does not mean that engineers are powerless in this respect. In our view, they are free to urge such initiatives in a timely manner. That is, our study constructs a second-order responsibility for engineers, one that urges them to strive actively for the creation of conditions on the engineering work-floor that enable the assumption of moral responsibility by individual engineers.

## Notes

1 Compare for example: Martin and Schinziger (1996). This much-used book defines engineering ethics as (1) the study of the moral issues and decisions confronting individuals and organisations involved in engineering; and (2) the study of related questions about moral conduct, character, policies, and relationships of people and corporations involved in technological activity (p. 23; also quoted in Lynch and Kline 2000, 196).

2 See, for example, Duff (1998) or Velasquez (1998). But any other textbook will roughly give the same conditions, albeit phrased differently or with a different emphasis.

3 Compare, for example, Velasquez (1998). A lot of debate centres on the question of whether a person is always responsible if these four conditions are met. For example, if I freely and knowingly cause my competitor to go bankrupt, am I morally responsible for his or her misery? However, there is considerably less disagreement on the opposite question: Can one be held responsible if one or more of these conditions is *not* met? In everyday reality, we seem to agree that in that case, we do not hold a person responsible for her or his deeds and their consequences. However, more often than not, it is a matter of degree as to how far these ideal conditions are met: you *co*-caused the action, you foresaw *some* of the consequences, you had *some* freedom to perform the actions (or not), etc. This means that responsibility is often not completely annihilated when conditions are not perfectly met, but *mitigated*. However, the mitigating power of circumstances is itself a matter of relative weight: if the consequences of our acting (or not) are very serious or severe, a simple reference to our lack of foresight will often not do: even if you did not fore-

see the consequences, this does not lift your responsibility because you *should have known*.

4 Compare Vaughan (1996) who shows that, in fact, there was no clear opposition between engineers and management. This opposition was construed afterwards to fit the prevailing conceptions of the professional responsibility of engineers.

5 As the rest of our article indicates, our contention is that networks do have agency in the sense that they enable and constrain the moral agency of the individuals they connect, but they have no *moral* agency. Of course, networks, institutions and organisations can be *made* responsible – as Shell was made responsible by Greenpeace for its intention to sink the Brentspar – but this is a pragmatic solution to the practical difficulty of pinpointing responsible individuals in complex network-like settings.

6 The suggestion made here can be further supported on the basis of outcomes from an evaluation study in which one of us participated. From this study – on the spending of governmental funds to research groups in the field of agricultural biotechnology – it appeared that most of these research groups had regular contact with a circle of clients from industry who consulted them about new directions and findings in academic research, as an input for the development of new product ideas. "Not only the small firms hunt us for new product ideas. You would be astonished to know how many big firms are milking us dry by inquiring about which new products they should develop," one researcher told the evaluators (Enzing et al. 1992).

7 Such expectations about the social role of scientists are revealed by occasional complaints from Dutch politicians about the lack of entrepreneurial spirit among academics. For instance, at the launch of a governmental program to support innovative start-up firms in biotechnology in early 2000 (to the value of €45 million), the Minister of Economic Affairs blamed the perceived Dutch arrears in biotechnology for this academic laxity.

8 To give an example of at least some diversity, the Energy Research Centre of the Netherlands (ECN) does much contract research work for the innovation- and market-oriented Ministry of Economic Affairs, propagating and implementing "green energy". In 2000, ECN also carried out a study for Greenpeace, to investigate how green "green energy" really is.

# The Cultural Politics of Prenatal Screening

*Marcus Popkema and Hans Harbers*

### *Future parents*

MAARTEN Only when I heard the heart beating did I realise that there's really something in that belly – a living creature with marble eyes, waiting to enter the world.

LOUELLA Maarten also talks to him. Everyday he says, 'Hello, here's your father speaking!'

MAARTEN Mostly when we disagree about something.

LOUELLA Then he explains why I'm wrong.

MAARTEN Particularly when she's eating too many sweets again. (Leans towards Louella's belly) 'Hello, so many sweets are not good for you, remember!'

LOUELLA But, what I really miss is that I can't go out for a few drinks once in a while.

MAARTEN Particularly when you see other people …

LOUELLA … having a good drink and getting tipsy.

MAARTEN It's funny to hear our parents say, 'Oh, but in our days we didn't worry about those things.' For example, Louella doesn't eat red meat either, because of the Lysteria bacteria….

LOUELLA Oh boy, no, that's toxoplasmosis, you always mix up everything.

MAARTEN … and then they almost get upset because we're concerned about such issues. They didn't worry, and yet we are doing well, aren't we?

LOUELLA What is really difficult for me are all those ethical questions you are suddenly confronted with.

MAARTEN Like, will you take an amniocentesis or not?

LOUELLA They recommend it if you are over 36. I am 35, so I could hide behind this rule.

MAARTEN But the question is: won't you ask yourself for the rest of your life whether you evaded something that you could have done?

LOUELLA But you can't reason those things logically. It has so much to do with emotions. We will see what it brings.

(From: *De Groene Amsterdammer*, Dutch weekly, 29 May 1996)

Maarten and Louella: Just a modern couple, expecting their first baby, pretty excited and a bit childish. Nothing special, the usual behaviour of future parents. Nonetheless, Maarten and Louella are pregnant in a different way than their parents were. They did not worry about *Lysteria* bacteria and toxoplasmosis, let alone amniocentesis. Maarten and Louella do. They live in a techno-scientific world. It is this world of extended scientific knowledge and a whole range of medical technologies that generate a huge gap between Maarten and Louella and their parents. Future parents nowadays have to cope with all these new medical techniques, whether they like it or not.

Examples such as this one involving Maarten and Louella give rise to concepts like "technological culture", referring to a world in which technology is more than an innocent instrument in human hands. Technological artifacts, so the story goes in science and technology studies, have their own program, far beyond the level of mere technicalities. They actively shape our lives. Consequently, the modernist notion of technology, based on technical neutrality and instrumentalism, is replaced by the idea that, to use Winner's (1980) well-known phrase, "artifacts do have politics". But what does this slogan mean? Of course, technological artifacts and developments have political effects. But what is surprising about that? We have known this since the industrial revolution – when technological developments drastically changed class inequality. Perhaps there is more at stake, i.e., technological artifacts not only have political effects, but are loaded with social relations and moral rules. That is: *politics incorporated* – technological artifacts as social and political actors.

Our first issue then is technology embodying sociality and morality. But what are the consequences of this presumed politics *within* technology for the more traditional policies *of* technology, such as steering, control, stimulation, setting priorities, etc.? In addition to the concept of technology, the notion of politics is also at stake here – including, of course, their mutual relationship. What are the effects of a redefinition of technology as a social, political and moral actor on those who are currently, i.e., in the modernist vocabulary, exclusively endowed with these capacities – human beings? What would it mean to them if political agency were extended to nonhuman entities like technological artifacts? And what about our very notions of "politics" and "agency"? That is our second issue.

In this chapter, both issues – technology as a political actor and its consequences for traditional (notions of) politics – will be dealt with by means of an empirical example: the career of a prenatal screening technique, so-called "serum-screening". In the first section, we reconstruct the evolution of the serum-screening test from its development in the laboratory to its implementation in (Dutch) clinical practice. In this part, we dive into the technicalities of blood analysis and its standardisation process. We argue that the serum-screening test is more than just an instrument to optimise and rationalise prenatal selection procedures. The test behaves like a "techno-normative artifact", i.e., a technique with a repertoire of normative actions. In the second section, we discuss in detail various reports of the Dutch National Health Council on serum-screening and the debate that accompanied the development of the Population Screening Act. This leads to a comparison of the politics *within* the very technology with Dutch governmental policies *on* and public debates *about* the same technology. The tension between them is remarkable because, while the new regime of pregnancy is continuously expanding and becoming normal as a result of the introduction of the serum-screening test, thus heavily structuring individual choices, the government, backed by public debates, tried to restrain and regulate this growing network by means of legislation (ratifying the Population Screening Act) and by mobilising the principle of "informed consent" in order to guarantee freedom of choice for pregnant women. But these attempts to forestall so-called "medical-technological motherhood" appear to have only limited success. We shall show that this is due to decisions that were made earlier and elsewhere – at the drawing table in the laboratory where the test was designed and in clinical settings where the test was regulated and further developed for practical implementation. In conjunction with the act of delegating competencies to a technological artifact like the serum-screening test during these early stages of design and development, a normative position has been smuggled into clinical practice. This "incorporated normativity" appears to have a substantial impact on the room for choice and the action taken by relevant actors later in the process. Pregnant couples, for example, get saddled with questions and responsibilities which they did not ask for and, more problematically, which they have trouble coping with. Meanwhile, politicians are held accountable for situations they did not create and can only marginally regulate. This leads us, finally, to doubt conventional responses to such situations: viz., restoring parents' and politicians' normative capacities as human agents in order to overcome these constraints on accountability and responsibility – as if man were simply the measure of all things. Perhaps there is something wrong with our very notions of agency (human or otherwise), normativity and politics underlying this modernist device.

## Serum-screening in lab and clinic

Several techniques are available for learning more about the fetus including amniocentesis, chorion villus biopsy, and ultrasound scanning. Since it is neither necessary nor possible to offer all of these techniques to all pregnant women, selection criteria are used. In most Western countries, women over a certain age (in the Netherlands this is 35 years) and women with a congenital defect are offered a prenatal diagnosis to detect possible congenital "faults".

Another way of selecting women for prenatal diagnosis has been under development since the early 1970s. A pregnant woman's risk of bearing a child with Down's Syndrome (DS) or a neural tube defect (NTD) can be calculated by means of a simple blood test. Only a single blood sample after 16 weeks of pregnancy and a little chemical analysis are needed. Women who appear to run a high risk of having a child with DS or NTD will be considered for subsequent prenatal diagnoses like amniocentesis or chorion villus biopsy. If made generally available, this selection test, also known as serum-screening, would render the current, rather crude criteria for these diagnostic techniques redundant, thus improving the efficiency of prenatal diagnostics. With the same level of diagnostic treatment, more fetuses with DS and NTD could be detected, and more, unnecessary treatment (in retrospect) could be avoided – which is not unimportant since these diagnostic techniques are not without medical risk, are invasive, and are psychologically taxing. From this point of view, serum-screening is a neutral instrument, optimising the selection for amniocentesis and chorion villus biopsy, but otherwise leaving intact existing practices concerning prenatal diagnosis. Closer analysis, however, indicates that this simple piece of technology is not entirely innocent.

### *From AFP to triple test*

For more than 40 years, alpha-fetoprotein (AFP) has been associated with problematic pregnancies. At first, there was only a vague hint about the possible role of AFP in pregnancies that did not develop regularly. But, in the 1970s, several biomedical research groups put forward more precise claims about the correlation between the level of AFP in the mother's blood and an abnormal development of the fetus. Seppällä and Ruoslahti (1972), two Finnish scientists, compared levels of AFP in the blood of pregnant women with the AFP levels in the blood of non-pregnant women. They concluded that levels of AFP were significantly higher in pregnancies that resulted in the birth of a stillborn child. At the same time, Brock and Sutcliffe (1972), two Scottish researchers, reported increased levels of AFP in the amniotic fluid of pregnancies that terminated in the birth of a child with NTD.

Both the Finnish and the Scottish researchers connected higher levels of AFP to an abnormal pregnancy. The Finns found these levels in the mother's blood; the Scots in the amniotic fluid. Next, Brock and Sutcliffe postulated a possible relation between these two findings. "Possibly the raised amniotic fluid AFP that we have found in anencephaly and myelocoele spina bifida may also find its way into the maternal serum... AFP crosses the placental barrier and may be found in maternal serum" (Brock and Sutcliffe 1972, 199). According to these authors, their results suggest that AFP measurements are valuable in the early diagnosis of NTD, enabling termination of these pregnancies (1972, 197). Thus, simple testing of AFP levels in the blood of the pregnant woman would provide the prospect (a) to make amniocentesis superfluous and (b) to develop a detection system for NTD pregnancies. In contrast to amniocentesis, which entails the risk of a miscarriage and is therefore used only under strict conditions, the AFP test could be offered to women without any restrictions whatsoever. This prospect was received enthusiastically within the international research community (Brock et al. 1973).

In this early period of serum-screening development, attention was primarily devoted to *increased* levels of AFP in the mother's blood. In the early 1980s, researchers also became interested in *lowered* levels of AFP. The reason for this is highly coincidental. A pregnant American woman had undergone the AFP test. Her AFP levels were measured two times, and both times they were "below sensitivity", so there was no reason to worry. To the consternation of all concerned, she gave birth to a baby with DS. The mother simply did not want to reconcile herself to the situation and tried to find a research group that would be interested in investigating her case. She succeeded and got in a new analysis after a while. On the basis of all the available data in the US on pregnancies and AFP levels, it is suggested that lowered AFP levels are a sign of what the researchers call "fetal chromosomal abnormalities" (Merkatz et al. 1984). And, just as in the case of NTD, it is suggested that the AFP test could be used for the diagnosis of DS in a routine screening setting.

During the late 1980s, another step was made in the development of the test. Until that point, attention had only been devoted to the protein AFP. There are, however, many more proteins in the mother's blood that play a role during pregnancy. In this period, efforts were made to ascribe new significance to these proteins. A number of proteins have attracted the special interest of most of the researchers in the field. Many of them think that a lowered AFP level is the result of low AFP production in the fetus's liver. Two other proteins, unconjugated estriol (uE3) and human chorion gonadotropin (hGC), are also produced in this organ. Thus, unusual levels of these proteins could also be a sign of the occurrence of DS. After a number of trials, the researchers did indeed establish a connection between the concentrations of these proteins in the blood of the mother and DS. Because of the combination of the measurement of levels of three proteins, the test is called the "triple test".

What else is happening here, besides the achievement of cognitive and technical progress? First, the protein AFP is accredited with the ability of indicating a fetus with NTD. Consequently, an *active connection* is made between the technical opportunity to make this identification and the normative wish to prevent the birth of a child with NTD.[1] By using words such as *malformations* and *disorders* in their research report, Brock and Sutcliffe express that, in their view, the birth of children with NTD should be prevented. However much implicitly, they thus anticipate a society in which the chance of having a disabled child is no longer perceived as natural. The wish to prevent the birth of an NTD child becomes *inscribed* in the technique that is used for the detection of AFP levels.[2] Of course, this type of wish is neither new nor determined by the specific technique. The prevention of harm is part and parcel of medical practice and is underlined by every practitioner in medical care. And the very same wish has been inscribed in amniocentesis for a longer period. What is new here is the opportunity to develop *large-scale* programs to prevent the birth of NTD children. The realisation of this opportunity takes for granted that it is worth striving for the *systematic* detection of NTD fetuses, with abortion as an ultimate aim. This normative position becomes incorporated into the AFP test – especially, as we shall see, in the way it is becoming standardised and organised in clinical practice.

The same applies to the triple test. Here, AFP and later on two other proteins are also believed to indicate malformations, in this case children with DS. A lowered AFP concentration in the mother's blood after a few months of pregnancy means a higher chance of having a child with DS. The wish to prevent the birth of a child with DS becomes inscribed in the methods of detecting AFP (and other proteins) levels in the mother's blood. Just as in the case of NTD, a normative act is connected to these methods: it is worth aiming for a systematic detection of fetuses with DS, with the subsequent possibility of aborting them. And here, too, this active connection between technology and morality is strengthened in the transition from the laboratory to the clinic, i.e., by the way the test is organised and standardised for clinical use.

### *Standards and statistics*

Soon after the development of the AFP test, the relation between raised levels of AFP in the mother's blood and an occurrence of a fetus with NTD did not appear to be as obvious as had been conceived. Whereas an AFP measurement of amniotic fluid could be carried out rather precisely, the measurement of AFP levels in blood resulted in much less significant data. This meant that the blood test should always be followed by an amniocentesis, in order to determine definitively whether or not the mother is carrying a child with NTD. Consequently, the initial goal of replacing amniocentesis with the blood test was set aside. Yet, an amniocentesis is expensive, risky, and aggravating. Therefore, the idea of using the blood test as a means of selecting women for amniocentesis was advanced. The task of selection for further detection necessary for realising the wish to prevent the birth of children with NTD, is *delegated* to the test.[3] The researchers in the field however, realised that this alternative use of the test would only be successful if its statistical performance could be improved. Thus, an effort to standardise the test procedure followed. After all, large-scale use of the test cannot be presented without proper standards.

Due to differences in populations and in methods, it is rather complicated to relate all the test results from the various research sites. In the UK, a mathematical procedure was developed to solve this problem. Via the multiple of median (MOM), data from the various hospitals were made comparable.[4] The test results are expressed in terms of the median of the levels of AFP in the blood of mothers from the population of pregnancies without defects. This standardisation effort, however, is not a purely statistical-technical matter. It possibly brings about unequal distributions in the availability of the test – a socially and normatively important issue. In the Netherlands, this issue was dealt with in a different way, because of the unequal distribution of availability. In the late 1970s, a Ph.D. research project was started on the AFP test in the academic clinic of the University of Groningen. As the first results seemed promising, 40 other Dutch hospitals also became interested in the new methods. However, one of the gynecologists in Groningen, Dr Huisjes, advocated a moderate attitude towards these developments (Huisjes et al. 1981). A proper use of the test, he argued, needed careful attention. For example, the MOM method requires every centre to develop its own frame of reference. Populations and methods differ at distinct locations. Thus, data from centre A cannot be used as a point of reference at location B. In order to meet statistical requirements for producing proper data, many measurements have to be carried out at one location. This requires a well-equipped laboratory infrastructure. Accordingly, Huisjes argued for a centralised implementation of the test. Statistical requirements to guarantee a correct frame of reference can only be met in such a centralised infrastructure, he claimed.

The same applies to the use of the AFP test for large-scale screening for DS. When this second application of the AFP test was developed, pregnant women in most Western countries were being selected for internal diagnosis on the basis of their age. Two main methods were used in the clinic to distinguish a "normal" pregnancy from a DS case. The first method was to make an analysis of genetic material from the cells of the fetus, which were extracted from the amniotic fluid (karyotyping). The second way to determine a fetus with DS was to breed some of the chorion villus sampling from the surface of the placenta, and subsequently perform a karyotyping. The latter method is known as "chorion villus biopsy". The procedure of the AFP test is now compared to this practice. Is there any additional value in performing the AFP test? At first, it seems rather disappointing. Just as in the NTD case, the margin of error is disappointingly large.

According to clinical researchers, however, this is no reason to discard the AFP test in prenatal diagnoses for DS. Standardisation does increase the predictive value of the test with respect to DS. It requires quite an effort from the researchers involved in statistics, but ultimately, it does become possible to develop a frame of reference that helps to determine relatively easily the chance of having a child with DS. By combining the AFP test with screening based on age, an increase in the effectiveness of the screening procedure seems possible. A positive effect of this combination of techniques is that the same number of DS cases can be detected with a lower number of amniocenteses and/or chorion villus biopsies. However, as with NTD, the performance of a large number of measurements remains conditional. And again, this requires standardisation and centralisation.

Although statistical requirements do not influence the testing procedure as such, they evidently do have an effect on the organisation of the provision of these services, and thus on their availability. A possible result is that pregnant couples who live near a centre where the test is offered will be more likely to undergo the test than those who live further away. Even a seemingly technical detail like the standardisation of the test is connected with normatively relevant questions, e.g., regional inequalities in accessibility. This kind of internal linkage between technical, social, and normative issues is all the more persuasive in matters of information procedures.

*Informing pregnant women*

Besides standards and statistics, Huisjes used a second argument for moderation and cautiousness concerning the introduction of serum-screening in the clinic as part of prenatal diagnosis, viz. its huge social impact. The AFP test makes it possible to calculate every pregnant woman's individual risk of having a child with NTD. But, leaving aside for a moment the question of whether pregnant women would decide to make use of this test or not, the bare option itself already raises some serious practical problems. For instance, what should one tell a woman if raised AFP levels have been detected? Huisjes believed that specialised teams were required to cope with difficulties in communicating these kinds of test results. Again, this pleads for a restriction of the number of institutes allowed to provide the test. In order to learn more about this social impact, Huisjes, in co-operation with medical sociologist Tijmstra, started an inquiry into the social and psychological consequences of the introduction of serum-screening in gynecological practices.

The AFP test has two possible outcomes: either the offer to perform an amniocentesis if an AFP level higher than 2.5 times MOM is detected, or a reassuring message if the concentration is below that value. The amniocentesis is used to make the final diagnosis. If a fetus with NTD is detected, the opportunity of aborting the fetus is discussed. Other "treatment" is not available. This is a very delicate matter, and therefore the proper organisation of the entire procedure is necessary. It cannot be assumed that everyone wants to perform an abortion if a fetus with NTD is detected. The provision of information therefore requires careful attention. Tijmstra and Huisjes (1983, 544) conclude that information has to be given in such a way that the pregnant couple can consider their opportunities themselves. If serum-screening were ever to be offered to the entire population, then Huisjes and Tijmstra would plead for a combination of written information, with the option of a consultation.

To prevent pregnant women from running into moral conflicts, Huisjes and Tijmstra want to provide extensive information in advance. Only then, they argue, are women and their partners able to think about the consequences of the test before the blood sample is taken. Though praiseworthy, this plea for the provision of information can also be interpreted in a different way. Taking into account the norms inscribed into the test, information functions as a means of transfering responsibility for the use of the test from the designers to the users. By delegating the task of selection for detection of NTD to the test, researchers like Brock, Sutcliffe, Seppällä, and Ruoslahti made an active connection between this test and their idea of preventing the birth of children with NTD. When the test is performed, this incorporated connection is automatically activated whether the users of the test agree with its morality or not. If pregnant couples are made responsible for the use of the test via the provision of information, they also subscribe to the incorporated norm. And, paradoxically enough, even if pregnant women were to consider *not* performing the test, it is they who are held responsible for the possible consequences of this choice.[5]

Sometimes this leads to what Tijmstra (1987) calls "anticipated decision regret". That is, pregnant women choose to put themselves through the test to dispel of their anxiety surrounding the uncertainty of not having done so. They try to avoid the future situation of "what if I had known before". In Maarten's words: Won't you ask yourself the rest of your life whether you evaded something that you could have done? Dynamics like these show that the mere possibility of performing the test already pushes pregnant women and their partners to thinking about the question of whether or not they would abort a fetus with NTD. They cannot escape the new questions that arise from new prenatal diagnostic techniques – a pressure that becomes stronger the more generally available and accepted the test is, as we shall see in the next section.

From this short review of the development of serum-screening in the laboratory and the clinic, we can conclude that even a simple piece of prenatal technology like a blood test is not a neutral, strictly technical, scientific affair. On the contrary, technologies like these deeply encroach upon the pregnancy and everything attached to it. First of all, the triple test is inextricably connected with a medical program focused on preventing defective lives. Although most people will not dispute this ambition, there are good reasons for being suspicious, even on this general level. Isn't technology implicitly facilitating a society within which it is no longer self-evident that one can give birth to and care for a child with a congenital handicap? Furthermore, additional objections can be anticipated about the sole means to reach that preventive goal, in this special case, an early abortion. Despite such objections, this "therapy" is enclosed in the diagnoses of serum-screening right from the outset. Even apart from such existential issues, the triple test itself imports something new into the world of pregnancy and reproduction: the possibility of tracing and excluding children with DS and NTD *on a large scale* – that is, not based on individual diagnosis, but on mass prognosis. The clinical organisation of the triple test, its methodological standardisation as well as its procedure of information *ex ante* and *ex post*, are attuned to this massive scale. This leads to a new "network of prenatal care" from which nobody can ultimately escape. Even the choice to not participate in this network should be made explicit, bringing about so-called "anticipated decision regret" – a phenomenon which, in turn, undermines this very choice.

Thus, not only the "pre-conditions" – the rules, the facilities and the procedures of pregnancy are changed by new technologies like the serum-screening test, but also the experience, the meaning, and the emotions of being pregnant. More than only being *conditional*, prenatal screening technologies are *constitutive* of what it means to be pregnant nowadays. The connection between technology, normativity, and sociality is not merely a passive one – a matter of artifacts only *having consequences for* a world of "humans-among-themselves" (Latour 1993[a]). On the contrary, it is an active connection whereby processes of inscription and delegation, normativity and sociality are *incorporated into* technological artifacts. Consequently, the triple test behaves like a *techno-normative artifact* – i.e., a technique with a normative repertoire of actions.[6] Since the wish to trace and eventually abort children with DS and NTD is "inscribed" into the test and embodied in the routine actions surrounding it, this artifact actively constructs new meanings and practices of pregnancy. On an individual level, prenatal screening in general, and serum-screening in particular, change the way pregnancy is perceived and experienced. Women like Louella feel reluctant to dedicate themselves to a pregnancy before all the testing has been done. Only when they have gone through the medical machinery, do they allow themselves to be "really pregnant" (Katz Rothmann 1986). The serum-screening test also leaves its imprints on a societal level. When this mode of prenatal screening becomes part of everyday routine in pregnancy care, the birth of children with NTD and DS is systematically prevented. To put it bluntly: a simple blood sample, being the raw material for the test, creates new kinds of pregnancies in a new society. On both the individual and the societal levels, the triple test generates new practices, new questions, new decisions to be made, and new structures of meaning, in other words, a new world-in-the-making of being pregnant, which the press anxiously typified as *medical-technological motherhood.*

## Serum-screening in (Dutch) politics and public debates

At the Dutch national political level, the same worry evoked a discussion about the desirability and possibility of restricting *massive* use of the triple test by legal means – by a law governing population-wide screening in particular. At the same time, there was a broader public debate going on among physicians, medical sociologists, policy makers, opinion leaders and, last but not least, the women involved, concerning autonomy and individual freedom of choice, in other words, would the introduction of the triple test expand freedom and autonomy, or are pregnant women increasingly getting caught up in a medical-technological network?

In the preceding section, we saw how a normative position became inscribed in a technical artifact by delegation. The serum-screening test incorporates the wish to have the opportunity to prevent the birth of children with DS or NTD. However, as long as this artifact remains within the laboratory, it can and will not effectuate this wish. Therefore, a clinical practice, including a complex set of rules, procedures and prescriptions, had to be developed. Only after the triple test becomes standardised routine can the test perform its intended technical and normative work. We indicated some of the problems and resistances that had to be dealt with – mainly focussing on methodological-technical issues (reliability, standardisation) and psycho-social factors (stress, anticipated decision regret). These *practical* problems – standardisation and mental burden – which researchers had to conquer when implementing a laboratory product in a clinical setting, are translated *politically* in public debates about legal restrictions on the massive use of the serum-screening test and the autonomy and freedom of choice of pregnant women, respectively. How are these public and political attempts to regulate the growing network of technologically advanced pregnancy related to the routines that have already been developed and established in the laboratory and the clinic? Will politics ultimately triumph over technology? Will humans rule the nonhumans – as the modernist doctrine wishes?

### *AFP test and population-wide screening*

In 1981, at the moment when only the screening for NTD was being considered, the Dutch Ministry of Welfare, Health and Cultural Affairs asked the Health Council of the Netherlands for advice on the desirability of the use of the AFP test as an instrument for population-wide screening. It was not until 1988 that the Health Council came up with a report on the topic, proposing to abandon a direct implementation of the test for screening purposes, since too many uncertainties still accompanied use of the test. Instead, the Council advised initiating a small-scale experiment, aiming at the reduction of these uncertainties. The clinic of the University of Groningen was explicitly recommended to perform the experiment, since this clinic had shown scientific interest in and already had some practical experience with the test.

This negative advice by the Health Council was positively interpreted in Groningen and the surrounding area. In a letter to all midwives, general practitioners, and other gynecologists in the northeast of the Netherlands, dated

10 May 1989, Mantingh and Beekhuis, two gynecologists working in the Groningen clinic, wrote that they were being bombarded with questions from the entire region about the experiment. The general availability of the test could no longer be prevented in this region, they observed. "People want to start now". Since no formal project was actually taking place, they made some suggestions for a provisional course of action, proposing procedures for the delivery of pregnant women's blood to the clinic in Groningen. They also advanced proposals for the way results are reported to participating women and for the way any eventual invasive action should be carried out.

In line with this (suggested?) high demand for the test and still waiting for the government's reaction to the Health Council's report, Beekhuis continued to prepare the commencement of a PhD project on the details of the test. Since the project began in June 1989, pregnant women can be tested in the Groningen clinic, upon request.

The governmental license for the experiment did not come as quickly as was expected in Groningen. The advice of the Health Council was not unanimous. One of the members of the advisory committee, the well-known geneticist Professor Galjaard, opposed the idea of performing a small-scale experiment with the test. This kind of project would not diminish the uncertainties involved in serum-screening. Surprisingly, the Dutch government followed Galjaard's (minority) advice. In a letter to Parliament, dated 17 October 1989, the Assistant Secretary of State for Welfare, Public Health and Cultural Affairs, Mr Dees of the liberal VVD party, explained that, in the absence of legislation on this matter, he had compared the AFP test with 5 criteria for screening, as used by the World Health Organisation: (1) the disorder that screening aims to alleviate has to be a serious health problem among the population; (2) an adequate research method is available; (3) subsequent diagnostics can be performed adequately; (4) the treatment is generally accepted and available; (5) the actual screening is accepted by the population.

According to the Dutch government, the AFP test only meets the first criterion. There are problems with the other four. The research method revealed too many problems (criterion 2). Too many women were needlessly referred to follow-up research, with the effect that too many couples became worried. A few healthy fetuses would probably also be lost due to miscarriage after an amniocentesis is performed. Moreover, not all of the disorders were diagnosed. And the number of referrals was high compared with other types of screening. Subsequent diagnostics, the third criterion, was insufficiently guaranteed. According to the government, this should have been organised centrally, while prenatal and obstetric care is largely decentralised in the Netherlands. The fourth criterion was not met either because there is no generally accepted treatment available. An abortion cannot be interpreted as such. Regarding the fifth criterion (acceptance by the population), the Dutch government made a distinction between mental burden and physical risk on the one hand, and freedom of choice on the other. The mental burden was thought to be considerable, while the risk of a miscarriage as the result of amniocentesis was unacceptable. Freedom of choice could be threatened in two ways, according to the Dutch government. First, a societal pressure to partake in a screening program might emerge. Second, the procedure was shaped in such a way that pregnant couples might experience confrontation with a *fait accompli.* As long as this procedure remains unchanged, as the government argued, the fifth criterion cannot be met.

Thus, there were enough reasons for the Dutch government to conclude that the AFP test did not meet the internationally accepted criteria for screening. This even led to the conclusion that a small-scale screening experiment in Groningen should be prohibited. This type of experiment would not reduce the uncertainties concerning the AFP test, since the proposed experiment in a limited area of the Netherlands was not directed towards an improvement in the quality of the methodology of testing.

After a new government was elected, at the end of 1989, the new Assistant Secretary of State, Social Democrat Simons, agreed with the standpoints of his liberal predecessor. His reservations about the AFP test as a screening method were backed up by the parliamentary Committee on Public Health. Some members of the committee were even more critical of the entire issue. In a discussion about the advice of the Health Council, it was particularly the Protestant parties in parliament who expressed their disapproval of the test. A screening program based on the premise that children with NTD are better off being born was reprehensible to the Christian Democrat Laning. Leerling, a member of the right-wing Christian party RPF, supported her by insisting that handicapped children also have a right to live. And Van der Vlies (right-wing Christian party SGP) raised objections to all types of selective abortion and thus regarded the entire discussion as unnecessary.

Whatever one might think of these views, they again make explicit and visible the normativities incorporated in the test. In subsequent public debates on prenatal screening, however, such critical voices soon appeared to be in the minority. The government's position, banning both large-scale screening and small-scale experiments, left one with the opportunity to perform the serum-screening test for NTD on an individual basis, providing the Groningen researchers with just enough room to continue their scientific studies.

*The conception of a "gray area"*

Gynecologist Beekhuis was unimpressed with the discussion in the Dutch Parliament. In a letter to the Committee on Public Health, 5 January 1990, he distanced himself from the Committee's opinions. First of all, according to Beekhuis, a mistake was made during the discussion. In the case of prenatal screening, it is inaccurate to only talk about false-positives and false-negatives, as the Government did, since the outcome of the test is a chance. Therefore, serum-screening cannot be compared with common forms of screening, i.e. for breast cancer. Second, Beekhuis was not convinced that abortion was a controversial topic in the Netherlands, as Parliament had stated. The termination of pregnancy after 18 weeks if DS is established is rather common practice in the Netherlands, thus why would an abortion in case of NTD be problematic? "Is DS worse than NTD?" Beekhuis asks rhetorically. Moreover, serum-screening cannot be stopped, he says. "An increasing number of pregnant women ask for serum-screening and are then offered it for free. The number of requests for research is increasing considerably, especially in the northeast of the Netherlands, probably as a result of the publicity generated about the planned experiment in the region. Apparently, 'the experts' viewpoint is unimportant – people simply want this test. Parliament and the experts thus can stop asking whether serum-screening is desirable. The test simply exists".

Beekhuis's letter was discussed in Parliament in early 1990. As a result, the Assistant Secretary of State, Simons, sent the Chief Inspector of Public Health to Groningen to figure out exactly what was going on. After the Chief Inspector reported back, Simons concluded there was no large-scale AFP screening going on in the northeast of the Netherlands, though interest in the test was increasing. "From the Chief Inspector and from letters from the Academic Hospital in Groningen, I understand that increased interest in AFP screening was initially generated by the expectation that an experiment with screening for NTD would be performed in this region; now this increase is based on a new use for AFP screening in combination with other tests, directed at the detection of chromosomal abnormalities (Down's syndrome) in the fetus" (Dutch House of Commons (*Tweede Kamer*) 1990, 3). In short, according to the Dutch Government, no screening was going on, only a scientific study aimed at extending of the test for DS, which generated an increase in the numbers of people interested in the test.

This is a tricky position, however. The government's stand generates a "gray area" where rules about what is allowed and what is not becomes increasingly fuzzy. A crucial factor in this matter is the way one defines and handles “individual requests”. Both Dees and his successor Simons allowed screening upon individual request. But what is an “individual request”? A doctor can always inform a couple in such a way that they decide to ask for serum-screening. Moreover, the growth of this kind of gray area is in any case stimulated by people’s tendency to exclude all possible health risks – a tendency reinforced by the phenomenon of anticipated decision regret (Tijmstra 1987; Tijmstra and Bajema 1990). “I don’t want to later regret my decision to not be informed” is a reasonable thought in itself, but has the unintended consequence of stimulating the expansion of the network of prenatal diagnosis. The difference between research on “individual request” and organised population-wide screening becomes smaller, and the gray area grow continues.

### *Broad or narrow “provision”*

The discussion thus focussed on the issue of “individual request”. Several stakeholders gave their opinions. In a proposal for a Population Screening Act, the Dutch Government defined screening as “a medical examination of people that is performed to carry out research that has been provided to the entire population or a category of it to find people, for their own benefit, with particular features or particular risk indicators”.[7] But what does this “provision” mean? KEMO, an advisory committee on ethical issues in medical research, stated that with serum-screening there is no supply of medical care. Since pregnant women have to ask for the test themselves, the test cannot be defined as screening. According to KEMO (1992), serum-screening should be interpreted in the same way as the selection practices for, prenatal diagnosis based on age, obliging a doctor to *inform* women about the opportunities for diagnosis. Since the latter is not recognised by the government as a form of screening, serum-screening should not fall into this category either. Thus, by making a distinction between “provision” and “information”, KEMO tried to keep serum-screening away from the medical-legal terminology under which Assistant Secretary of State Dees had subsumed it.

The Health Council of the Netherlands (1994) favoured another interpretation, which became clear in its report on genetic screening. Like KEMO, the Health Council compared serum-screening to an age-based selection of pregnant women for prenatal diagnosis. However, the Council reached exactly the opposite conclusion as KEMO had: Selection of pregnant women for prenatal diagnosis based on age should also be recognised as a form of screening. The Health Council took this stance on the basis of another interpretation of the word “provision”. This key word in the Minister’s definition of screening, it said, was not sufficiently discriminating. If "provision" is read in a narrow sense, not including individual requests for information, then the selection of pregnant women for prenatal diagnosis based on age indeed cannot be defined as screening. However, if "provision" is read in a somewhat broader sense to include systematic information, as the Health Council preferred, then even this type of selection should be recognised as screening – let alone selection based on the blood test. So, by using this broad definition of "provision", the Health Council qualified both selection methods as screening and thus placed both under the legal restrictions of the Population Screening Act, implying the requirement of a Ministerial permit, for example to establish any screening program.

The Health Council defended this stance by emphasising what it considered to be the ultimate goal of serum-screening, which was not the stimulation of selective abortion in order to prevent the birth of children with DS or NTD (later called *genetic cleansing*; Clarke 1997), but the provision of choices for pregnant women and their partners – either to have the pregnancy terminated in the event of an abnormal result, or to prepare them for the birth of a child who may possibly be severely handicapped. Optimal information is crucial for reaching this goal, given the emotional, social and, organisational complexities of serum-screening. Within this perspective, there is no sensible distinction between "provision" and information, and consequently, serum-screening should be put under legislative rules.

In order to keep a legal grip on serum-screening, the government had to follow the Health Council's advice, even if this implied an extension of the Population Screening Act to selection based on age. And that is indeed what happened. In March 1996, just a few months before this Act was approved, the Dutch Minister of Public Health, Borst, stated in a parliamentary debate that both selection methods women for prenatal diagnosis would be recognised as forms of screening. Consequently, a permit should be requested at the Ministry of Public Health for both practices, applying the stringent criteria as originally proposed by former Assistant Secretary of State, Dees. Thus, the chance that serum-screening would be permitted decreased considerably, not only because of the scientific and organisational uncertainties surrounding the test – legal criteria to refuse a permit – but also because a permit for screening for diseases or abnormalities for which treatment or prevention is not possible would only be issued, according to the Population Screening Act, "if special circumstances provides justifiable grounds". DS and NTD are such untreatable abnormalities; and abortion, the Parliament stated, cannot be regarded as a form of prevention.[8]

In brief, institutions like KEMO did not succeed in defending serum-screening away from the criteria that are applied to "conventional" forms of screening. Others, like the Health Council, were successful in their efforts to link serum-screening to the medical-legal rule-set for screening. In fact, since the old types of selection were also defined as screening from this point onwards, the practice of prenatal diagnosis has become even more attached to this rule-set, offering the government the opportunity to regulate or even to forbid the test as a form of screening.

Should we interpret this as a success story – a triumph of politics over technology? There are good reasons to be skeptical. Surely, after many years of discussion about the question of whether or not the serum-screening test should be subsumed under the existing rules on population-wide screening, this question seems to have been answered positively, giving the national government a legal instrument to regulate, limit, or prevent the public and massive availability of serum-screening. However, this political fact in favour of central governmental intervention was only reached after a substantial stretch of the legal definition of "population-wide screening" – so much so, that the crucial distinction between individual diagnosis and collective screening almost vanished. In conjunction with the upscaling of the triple test – internally propelled by the request for standardisation and externally by an increasing demand for prenatal diagnoses – the gray area between individual demand and collective supply has become increasingly crowded. While politicians, policymakers, and administrators still discuss and reformulate this borderline, the network of pregnancy routines, including the triple test, is expanding and gets stabilised. In this relatively autonomous process, the limits of what is politically permitted and what is technically possible changes on both sides.[9] In short, parliamentary democracy does what it should do, but its margins for policy yet again appear to be very small.[10] Maybe the public debate about screening, aiming at guaranteeing freedom of choice and the autonomy of pregnant women and their partners, will be more successful in restoring the power of humans over nonhumans.

### *Autonomy and freedom of choice*

KEMO, we saw, opposed the Health Council and government's views on the classification of prenatal diagnostic practices as screening. Serum-screening, according to KEMO, is a risk estimation in order to keep as many women with healthy pregnancies as possible away from prenatal diagnosis. It is only a form of pre-selection for diagnostic research, just like the selection of pregnant women on the basis of age – but much more precise. Moreover, legal inequality related to the age criterion is avoided when serum-screening is used as a method of selection. If accompanied by the proper information and advice about the specific character of the test (a calculation of probabilities), KEMO believes it is worth offering every pregnant woman the opportunity of having the test and considering amniocentesis.

Within this perspective, serum-screening increases the freedom of choice of pregnant women, typified as rational, calculating actors. Not everyone agrees with this optimistic view of prenatal diagnosis. For example, Van Berkel and Van Wingerden, two Dutch female sociologists, think that KEMO's opinion is a trick to make the disadvantages of serum-screening disappear. In their view, the difference between screening and risk estimation is not as clear as KEMO would like to suggest. If the person providing information is also involved in the performance of the test, then the act of informing includes the possibility of further consequences. This puts pressure on the pregnant woman, which cannot be removed by idealising her freedom of choice. Van Berkel and Van Wingerden thus fear a practice in which individual risk estimation develops into an informal screening program. They do not favour an expansion of medical care in pregnancies because then every woman is perceived as a risk case. The development of prenatal care combined with the idea of freedom of choice transfers responsibility for the use of the technology to the pregnant women, according to Van Berkel and Van Wingerden (1993).

The two sociologists put their fingers on a sore spot. Those who emphasise women's individual freedom of choice regarding whether or not to undergo serum-screening, like KEMO, perceive the triple test as neutral technology, as an instrument without value – to be used at will. This is exactly what appears not to be the case. Normative issues and technological artifacts like the AFP test are intimately tied up in a network of routines that is woven around serum-screening as a kind of prenatal medical care.

The Health Council, showing much more reservation than KEMO about the introduction of the serum-screening test, does address this intimate relation between norm and technology. In its report on genetic screening, the Health Council acknowledges that future parents, even if prenatal screening is supplied, will be confronted with the possibility that their child may be malformed. This can effect a tentative pregnancy that is discussed until it is proven that the child is normal and healthy. And, vice versa, widespread serum-screening can cause an unfounded comfort about the pregnancy instead of a more realistic view that pregnancy and birth are inherently related to uncertainties and risks. Moreover, feelings of guilt and regret may arise for those who did not undergo the test and subsequently gave birth to a child with congenital disorders.

According to the Health Council, these issues show that any kind of provision of screening is, by definition, not value-free. Serum-screening indeed enriches the freedom of choice of pregnant women. The option of avoiding giving birth to a baby with DS or NTD becomes a real choice. But, at the same time, their autonomy is put under pressure. The opportunity to ignore this piece of prenatal care is constantly becoming smaller. Provision, especially provision on a large-scale, enforces people to make a choice. Even if people neglect this provision, a choice is made. Consequently, the provider bears a considerable amount of responsibility. This is especially true in the case of serum-screening, which is followed up by only very limited, and contested, courses of action. Therefore, according to the Health Council, the supply of screening should be accompanied by an excellent provision of information, or even counselling and guidance. Truly free participation in a screening program should thus be ascertained. "After having been informed, people have to be able to ignore the provision of serum-screening.... Participation should not be so obvious that abstinence has to be defended. An increase of choices should not lead to a decrease of individual freedom. This will remain a precarious equilibrium. It should be avoided that an increase in opportunities of choice leads to restrictions of individual freedom" (Health Council 1994, 77).

Apparently, concepts like freedom of choice and autonomy have a Janus-like countenance: on the one hand, serum-screening increases the number of options for choice, whereas on the other, the room for not choosing at all, for evading the serum-screening test's repertoire of action, decreases. While some people and/or institutions involved in the public debate justify the introduction of all kinds of new options and choices on behalf of women's autonomy, others dispute that this development appeals to this same principle of autonomy.

Even though the Health Council gives more attention to normative issues in serum-screening than KEMO does, it also assumes that the course of events can be steered in the right direction by information, guidance, and counselling. Freedom of choice is supposed to be guaranteed by optimal information.[11] Ethicists partaking in the discussion also assume that the pregnant woman's autonomy is decisive in the acceptance of serum-screening. "Autonomous decisions are only possible if complete information is secured", according to Van den Boer-Van den Berg and Dupuis (1993). "A choice based on incomplete information could cause harm in the case of serum-screening". Though these authors are very skeptical about the opportunities for fulfilling this requirement and thus are not outspoken proponents of the test, their argumentation rests on the assumption that the pregnant woman can act autonomously and make free choices. Perhaps unintentionally but, just like

KEMO and, to a lesser extent, the Health Council, they still place the responsibility for the use of the test on the woman, thus assuming that the triple test is a neutral device to be used without any after effects, provided that women are fully informed. As soon as the information condition is fulfilled, humans regain their say over nonhumans, according to the logic of this style of ethical reasoning.

Even the medical sociologist Tijmstra, in his analysis of anticipated decision regret, which shows an excellent awareness of the normative effects of the serum-screening test, ultimately relapses into this logic of human autonomy over (medical) technology. He, too, mobilises the weapon of information to minimise the workings of this mechanism of anticipated decision regret.[12]

How can one evaluate this claim? Again, skepticism seems to be the proper attitude here. The public debate about freedom of choice and the autonomy of pregnant women shows the complexities and ambiguities of our technological culture. Of course, if well informed, a pregnant woman, especially one under 36 years of age without a hereditary defect, obtains extra options with the introduction of the triple test because she can choose to undergo the test or not; and if she does and she appears to be a high risk case, she can choose whether or not she wants further diagnoses. And if she really turns out to be pregnant with a child with DS or NTD, she can choose to give birth to the child or not – so at least the traditional story of individual choice applies here. However, the further the triple test and its accompanying network of practices extend, the more it becomes normal and routinised, and the less easily individual women can resist or avoid this network. Some routes of action become increasingly obvious, almost natural; others disappear from the map of pregnancy. Options like "not knowing" and "not wanting to know" will be increasingly marginalised. Paradoxically, optimum information contributes to this pressure from the network. Routinisation is intrinsic to the dynamics of information in that everybody is getting used to the practice about which they are so fully informed.[13]

Moreover, information has another effect as well, intended or not. Pregnant women are not merely "enriched" with an extra option, a new choice because within the logics of choice, an extension of possible choices necessarily implies an increase in accountability and responsibility. Thus, by informing pregnant women and leaving them the choice, these women also become exclusively responsible for the norm inscribed into the test: be aware of children with DS or NTD. The provision of information appeases the conveyance of responsibility. Other developments in the practice of serum-screening, such as routinisation and standardisation of testing and analysis, also contribute to this transfer. After all, in that case, it is the pregnant woman who takes the decision, she makes the choice, and therefore, according to the logics of rational choice, only she is ultimately responsible for its possible consequences. All the other elements in the network thus become facilitating links. Technical engineers, physicians, nurses, hospitals, medical technologies, etc. only furnish opportunities. It is the pregnant woman who does the decision making. Given this logic that more freedom of choice implies more responsibility, the suggestion to reduce the pregnant woman's burden by means of optimal information inevitably leads to an increase of responsibilities on her side. Nothing special is going on within this logic. But meanwhile, the attribution and distribution of both choices and responsibilities have radically changed. The advocates of information put the decision and the responsibility for the possible consequences unilaterally in the hands of the pregnant woman. As a consequence, other involved actors, like science, technology and health care institutions, are vindicated in advance. Their alleged neutrality is not a matter of fact, but the result of active attribution. By putting choice and responsibility exclusively in the hands of the individual woman, other involved actors are relieved of all responsibility in one and the same movement. They are actively (and effectively) neutralised. The distinction between scientific facts and technological instruments, on the one hand, and choices, norms, values and responsibilities, on the other, i.e., the demarcation between science/technology and politics, again turns out to be a major political act in itself.[14]

## Conclusions

In the first section, we followed the serum-screening test from its development in the laboratory to its implementation in Dutch clinical practice. Here, the test was shown not to be an innocent instrument in the hands of humans, merely optimising and rationalising prenatal selection procedures. On the contrary, by processes of delegation and inscription, the test was imbued with new normative options and social relations. Consequently, the serum-screening test became a normatively and socially highly relevant actor in the constitution of new kinds of pregnancy in new social contexts. We articulated this "world making" competence of the triple test by qualifying this test as a "techno-normative artifact", embodying new routes of action and, in that sense, also incorporating politics.

In the second section, we described how the test was politicised in quite another sense: as part of Dutch governmental policies of prenatal screening and as a hot issue in public debates. It was shown that the politics *in* the technology under discussion and its implied, relatively autonomous path of development severely restricted the margins for a policy *on* the same technology. Politics with a small "p", in the laboratory and the clinics, apparently sets limits for the discussion and action in institutions considered to be part and parcel of "genuine" politics, capital P which includes state, parliament and public sector. If scientists and engineers incorporate normatively relevant options in the material order they produce, there is not much room left for political deliberations within these institutions. Members of parliament, for example, can only forbid the serum-screening test or regulate its use. There was no firm discussion on the question of whether or not the test contributes to the benefits of life. Those who try to open such a debate, like the right-wing Christian parties, quickly find themselves in a marginal position. The choice for the test and its implied new worlds of pregnancy, sometimes referred to as "medical-technological motherhood", was made back in the early 1970s in the laboratory and the clinic. Obviously, traditional politics has lost some ground.

Moreover, we analysed the typical modernist political and public reaction to this perceived threat of technologically incorporated politics, such as the pleas for counselling and information in order to warrant women's autonomy and freedom of choice. This strategy of "informed consent" turned out to have a Janus-like countenance. By delegating a desire to detect NTD and DS in fetuses via a blood test, the goal of finding these congenital disorders becomes inscribed in the way the performance of the test is organised. These processes of delegation and inscription provide humans with the opportunity of choosing to abort a fetus with these disorders. Consequently, their abilities to exert power over their own lives increases. But this appeared to be only half of the story, ignoring the unintended consequences of information and counselling. The provision of information facilitates the transmission of responsibility. The more the triple test becomes an easily accessible and widespread technique, the more it becomes a normal and routine part of pregnancy, the more it normalises and disciplines one's approach. The choice to be uninformed, for example, is marginalised, since the simple existence of the test and its accompanying practices of information and counselling decrease the room for "ignorance". Thus, serum-screening has both an enabling and a constraining effect on pregnant women's agency – their autonomy and freedom of choice which is enabling in terms of being able to choose to abort a fetus with DS or NTD, but constraining in terms of losing the option to remain ignorant.

This Janus countenance of informed consent was explained by the dynamics of the heterogeneous network of new pregnancies-in-the-making, i.e., by processes of delegation and inscription as related to a redistribution of responsibilities. Pregnant women, as we saw, become responsible for the choice that is incorporated in the test. By providing pregnant couples with information about the nature of the test, the responsibility for its use is relocated to them. Consequently, those who developed and implemented the test are normatively vindicated. Thus, one could say, somewhere in the process of developing the practice of serum-screening, that it is not just the wish to prevent fetuses with DS and NTD from being born that is incorporated in the test, but the accountability for its use is also switched from researchers to pregnant women. They become exclusively responsible for what many actors have created. It is exactly this process of the delegation of competence and the shift of responsibilities that generates the ambiguities in the test. By providing the opportunity of individual choice, all pregnant women are saddled with a new responsibility, for as soon as people can make a choice, according to the logic of rational choice, they can be held responsible – even for not choosing at all, which is, following that same logic, also a choice. "But you can't reason those things logically. It has so much to do with emotions", Louella says. Along with Maarten she gropes for a way to handle this new world of pregnancy. It is apparently not an easy task – let alone simply a matter of rational choices.

This story about the serum-screening test resembles recent insights from science and technology studies fairly well, as read in its broadest sense. The coproduction of technology and society (Bijker and Law 1992), science and technology as politics pursued by other means (Latour 1983), processes of delegation and inscription redistributing responsibilities (Akrich 1992), artifacts having politics (Winner 1980), the displacement of politics (Beck 1997), technological cultures as *hybrid collectifs* (Callon and Law 1995); relational or interactive materialism (Law 1999; Harbers and Mol 1994; Harbers and Koenis 1999), ontological politics (Mol 1999) – all these notions fit our narrative of the serum-screening test. Albeit in different ways and from different angles, each of these notions contributes to the intellectual reconsideration of modernist theories of science, technology and society – particularly a whole set of internally related dichotomies constitutive of those theories, which includes facts versus values, science and technology versus politics, nature versus culture, causality versus intentionality, and laws versus rules. All these distinctions circulate around the separation between "things-in-themselves" and "humans-among-themselves" – a distinction Latour (1993a) and many others regard as central to the Modern Constitution.[15]

Part of this reconsideration of the modernist vocabulary is the ascription of agency to nonhuman actors like technological artifacts. We have done this in more than one way in our narrative about the serum-screening test. This test was shown, in the first place, to have both enabling and constraining effects on pregnant women's agency. Thus, a nonhuman artifact like the triple test can play a mediating role in extending and limiting human agency. But, secondly, this active role of the test was shown to be not only a matter of *effect*, but also a matter of *constitution*: artifacts not only have consequences for human agents, but they also are constitutive of human beings, e.g., pregnant women and their range of feelings, knowledge, and possible actions. By delegating the task of finding congenital disorders to a test and by inscribing the wish to be able to prevent the birth of children with such disorders into this test, a technological artifact, loaded with normatively contestable options, creates new social, cultural, and emotional relations. The triple test, like other prenatal screening techniques, is constitutive of a new world of pregnancy. In that sense this nonhuman is an inevitable agent.

This theoretical move towards (more) symmetry between human subjects and nonhuman objects, however, not only touches upon the object side of this dichotomy, subscribing agency to nonhumans such as technological artifacts, but also upon the subject side, i.e., pregnant women, their partners, their future children, as well as other involved human actors like politicians and citizens. Even the system of politics, as the alleged place *par excellence* for normative, intersubjective deliberation, is then at stake. Just as pregnant women's use of prenatal screening techniques can be evaluated as both an increase and a decrease in autonomy, politicians are confronted with new socio-technical configurations which they can at most regulate but can now no longer reverse. Politics and public will-forming are subordinated to these new conditions. Consequently, in cases like these, normative deliberation is not a free discourse, as the modernist conception of politics and normativity would wish to have it. In contrast – Politics, with a capital P, defined in this subject-oriented way, stands rather helpless and powerless with regard to socio-technical changes, since both the content and range of the political agenda are largely settled by developments that take place elsewhere. That is not to say that those developments are irreversible, and thus a politics of technology is impossible or useless. On the contrary, it means that a politics *of* technology should be connected much more closely to the politics *in* technology. With regard to technology, politics is not only *displaced*, e.g., from parliament to the laboratory, but also qualitatively *changed* from free deliberation *about* the good life, based on normative principles, to the making and unmaking *of* actual worlds. So, to be successful, any politics of technology should realise this transition – in the dual sense of the word 'realise': being aware of it and actually accomplishing it. The politisation of technological artifacts requires new, materialised ways of doing politics.

Our case study about the serum-screening test gives rise to the endowment of agency upon technical artifacts. But it also puts human autonomy and agency in perspective, including its consequences for (our conceptions of) politics and normativity. This is not a return to technological determinism or pessimism. On the contrary, it is an attempt to explain the analytical and normative implications of the co-production of technology and society, i.e., the mutual dependence of humans and nonhumans. Men are not always the measure of all things – and why should they be? At least Maarten and Louella are not; neither do they pretend to be. "We will see what it brings", they observe.

## Notes

1 For the notion of "active (and passive) connections", see Fleck ([1935] 1980).
2 For the "inscription" of social relations and normative rules into technological artifacts, see Akrich (1992) and Latour (1993[b]).
3 For the concept of "delegation", see Latour (1994).
4 In the mid-1970s, 19 hospitals in the UK co-operated in an effort to develop standards and points of reference in this field of research. This was necessary since there was no "natural level of serum-AFP which might be regarded as separating a high-risk group that would be further investigated for neural tube defects from a low risk group that would not" (UK Collaborative Studies 1977, 1324).
5 At this stage of the argument – but see later – we shall not discuss the very concept of "responsibility". The "only" point here is the *distribution* and *attribution* of responsibilities.
6 Surely, in general this applies to every artifact. But some of them, like the triple test, have a deeper and more forceful impact on practical decisions and actions than others since they are more solidly embedded in those practices by means of standardisation and routinisation in this particular case. Consequently, more work is needed, first, to allow them to appear as neutral, non-normative instruments and, subsequently, to deconstruct this false image by showing their normative load.
7 The Dutch government began work on this type of Act in the early 1980s; it passed through Parliament in 1996.
8 Reason enough, even for a cautious authority like the Health Council, to argue that in the case of serum-screening, there are indeed such "special circumstances", leaving scope (in principle) for this form of screening, even though abortion cannot be regarded as prevention, the test still provides new options for action, new choices – the very goal of screening as such (Health Council 1994).

9 A good example of this process is the advisory report, produced by a Health Council committee, on prenatal screening for DS and NTD (Health Council 2001). Whereas, in 1994, the major issue was whether serum-screening should be subsumed under a Population Screening Act-in-the-making, the Health Council now recommended a general introduction of serum-screening for DS and NTD, as "a superior alternative to the existing practice of maternal age-based screening" (p. 28/9). Legislation no longer functions as a means of *restricting* the general availability of the test, as some would have expressed it in those days, but as one of the means of *regulating* population-wide serum-screening, i.e., as a legal guarantee for the careful implementation of the triple test. Apart from a comparative inquiry into the effectiveness of age-based and test-based selection (with a positive end result for the latter), this change in inclination is grounded in scientific research that, according to the Health Council, shows that earlier medical, psychological, social, organisational, and ethical problems (whether these problems were real or alleged) have now been satisfactorily overcome with the introduction of the serum-screening test.

10 This is not a reintroduction of determinism in general – whether it be technical or social determinism, or some kind of hybrid determinism as in the network marches on. If we mention determinism at all, it should only be done in a localised and contextualised sense: For whom, at what time, and in which context should developments in the hybrid network be regarded as irreversible? (see Callon 1991 and 1995 on irreversibility). In our case: developments in the network of pregnancy are largely irreversible within traditional politics. But that does not imply that these developments are irreversible in general. On the contrary, it gives rise exactly to rethinking this very politics such as what, in this case, could be the adequate place, form and content of a possible politics of prenatal technology?

11 This applies to the Health Council's report of 1994, but even more to its 2001 report. *Providing choices* as the ultimate goal of serum-screening and *informed consent* and *counselling* as the guarantees for real autonomy and freedom of choice are the central categories here. Illustrative is the way the Health Council counters the argument of social pressure due to the routinisation and normalisation of prenatal testing. In fact, it says that this pressure is obviously not that strong since pregnant women themselves request the test. Moreover, if this pressure did actually exist, it would violate the autonomy of the women involved and their partners – a violation that can only be countered by optimal information and counseling (Health Council 2001, 125).

12 Here we come across an important difference between a medical sociological analysis in terms of, e.g., medicalisation and an analysis, like ours, rooted in science and technology studies. Whereas, in the first approach, the idea(l) of free humans as the measure of all things functions as the final guide for diagnosis and

therapy, the second approach emphasises the mutual dependence of humans and artifacts – in the descriptive as well as in the prescriptive sense.

13 Consequently, the Health Council's (2001) reasoning against the social pressure argument (see note 9) does not hold. It denies this paradox of information.

14 On the relation between morality and technology, see also Bruno Latour (2002).

15 Compare Pels et al. (2002) for a discussion of the status of the object in social science.

# Epilogue
# Political Materials – Material Politics

*Hans Harbers*

The starting point of this volume was the notion of the co-production of science, technology and society. Scientific knowledge and technological systems on the one hand and social, political and moral relations on the other hand are mutually constituted in one and the same historical process. This constructivist notion implies, first, a denial of any kind of autonomy of knowledge, power or morality. Cognitions, social relations and moral rules co-develop.[1] Second, the notion of co-production rejects any kind of reductionism or determinism. Developments in science and technology cannot be explained exclusively by their social and political context. But neither do science and technology determine our *condition humaine*. Technological means and human ends, instruments and interests, artifacts and desires – all are co-produced. Analytical priority is denied, both to technology and to humanity.

Thus, from the very start, two positions are eschewed: a humanistic voluntarism pronouncing that man is the measure of all things, and a technological determinism preaching that technology follows its own immanent logic.[2] Instead, following the principle of radical symmetry, both humans and nonhumans are granted agency. Or, more adequately, since agency is not an a priori quality of entities-in-themselves, but the result of developments in the hybrid networks of humans and nonhumans, the distribution of agency is analysed. Agency is every inch a relational characteristic – not the condition for, but the product of contextually situated, relatively contingent developments. This notion of relational and distributed agency is used by Disco in his attempt to integrate science and technology studies with general social theory; by Brey in criticising realism for its blindness to social representations and social constructivism for its neglect of "objective" physical constraints; by Oudshoorn et al. in uncovering inequalities in the design and use of a specific technological artifact; by Stemerding and Nelis in analysing the construction of different subject-positions in medical screening programs; and by Popkema and Harbers in detecting incongruencies between (sub)politics incorporated *in* a prenatal test and governmental policies *toward* the same test. Central to all these contributions is not what humans and nonhumans (essentially) are, but what they do – among themselves and vis-à-vis the other, without presupposing in advance any hierarchy between them. Ergo, the volume is tuned in a poststructuralist and a posthumanist key.

## Poststructuralism and posthumanism

The poststructuralist part is relatively easy to explain and to accept. While structuralism focusses on structured, more or less ready-made relations (of a cognitive, technical, linguistic, social, political, cultural, moral, or whatever kind), constructivism aims at contingent relations in the making. Framed in Lakatosian terms: structuralism and constructivism are research programmes with opposing heuristics. The first is directed towards tight structures, smooth systems, and undisturbed order; the second towards processes of ordering and re-ordering, action and re-action. Structuralism, so to speak, is bent on closeness and closing off, while constructivism is devoted to openness and opening up. Consequently, from a constructivist perspective, structuralism harbors four closely related horrors. First, the analytical horror of determinism, either in its technological or its sociological form, but always with only one line of development – necessarily and without contingencies – things could not have been different. Second, the political horror of fatalism. Since things go as they go, there is neither room nor a need for change or intervention. Third, the normative horror of moral emptiness. If structural developments are linear and inevitable, there is no place for critical moral judgements – neither by participants nor by analysts. As for the analysts, this leads, finally, to the methodological horror of neutrality: description and explanation is the only thing they can do. By bringing agency back in, opening up the possibility of new routes of action, constructivism tries to steer clear of these horrors: things can always go, or at least could have gone, differently. Thus, space is created again for critical judgement and change.

Surely, constructivism is not without its dangers either, as some of the authors argue. Disco criticises actor-network theory for its lack of sociological relief because, by granting agency to all the elements in heterogeneous networks, it tends to lose sight of the dialectics of agency and structure – the touchstone for an adequate understanding of social change and development. In the same spirit, Oudshoorn et al. draw our attention again to differences in power. In the process of co-production of technology and society – in this case the socio-technical relations constitutive of the Baby Watch programme – some voices are silenced – not by accident or at random, but in a structurally programmed way. Without denying the benefits of constructivism (its anti-essentialism and anti-determinism), they therefore eschew what they consider to be a too facile and undifferentiated embrace of agency, with its downplaying of structural constraints and inequalities.[3]

More hotly contested is the posthumanist aspect of radical constructivism, i.e., the dismantling of the human monopoly on agency in favour of a distribution of agency between both human and nonhuman actors. Though the position promises a welcome antidote to naïve and idealistic notions about human intentionality, autonomy and reflexivity, a number of authors, including some in this volume, warn against possible negative consequences of the principle of radical symmetry, viz. that we blind ourselves to differences and only see social and/or moral flatlands. Disco, for example, not only pleads for more sociological depth in terms of agency and structure, he also argues that the agency of nonhumans has a different logic than the agency of humans. While the first follows "natural law", the second is amenable to more traditional sociological explanations – either in terms of meaning and intentions or in terms of structures and institutions. Brey, in his argument about differentiated constructivism, makes a closely related point. Actor-network theory, or hybrid constructivism in his terminology, is shown to enable generalisations about affordances and constraints of artifacts inconceivable in a vocabulary that maintains the natural-social distinction. But only at the price of forfeiting detail: in particular the distinction between natural/technical and social/symbolic sources of nonhuman agency. Affordances and constraints engendered by artifacts, according to Brey, are sometimes physical in nature, and sometimes result from social representation – a differentiation that hybrid constructivism's persistence to the generalised principle of symmetry would forbid us to make, notwithstanding its importance for any possible intervention in hybrid networks, i.e., for technology policy.

Such analytical and conceptual arguments against radical symmetry become politically and normatively "hot" as soon as they are connected with the malleability of and the responsibility for specific socio-technical settings and ensembles. Swierstra and Jelsma, for example, argue that individual engineers cannot be held solely accountable for socio-technical developments inasmuch as they were only one of the many participants. Institutional complexities have their own social logics, (partly) depriving individuals of agency and thus (partly) relieving them of moral responsibility. But this shift of *social* agency from individuals to institutions does not in and of itself imply a shift of *moral* agency. Institutions and networks can never be held morally responsible, according to Swierstra and Jelsma, since morality is an affair of human individuals exclusively. And, implicitly, within this style of reasoning the same holds for nonhuman actors like artifacts. Thus, Disco's and Brey's differentiated ontologies acquire moral relevance in that all actors are loaded with agency – but only a few are blessed with moral agency.

Oudshoorn, Brouns, and Van Oost's analysis of diversity and distributed agency in the design and use of medical video-communication technologies is written in the same spirit. Though they accept the principle of radical symmetry as a useful conceptual and analytical instrument to reconstruct the distribution of agency among different actors in hybrid socio-technical networks, on an empirical level they only observe asymmetries – agency turns out to be distributed unequally. Some actors appear to be stronger than others. Moreover, the authors contest the principle of radical symmetry on the level of politics and normativity. Though, as they argue, both people and artifacts can act, only humans can be held responsible for the technologies they produce. Thus, human actors again make the final difference. And so we are back on familiar ground where responsibility (moral agency) is exclusively attributed to human actors, who are internally divided by unequal distributions of power (social agency) – this is the well-known vocabulary of traditional political and social theory.

Disco, Brey, Swierstra and Jelsma, and Oudshoorn et al. thus express serious reservations concerning the posthumanist face of radical constructivism – for analytical reasons, the supposed blindness to (power) differences; and for normative reasons, the fear of losing discursive space for moral judgement and political action. These reservations are thus inspired partly by the same fears that were expressed in reference to structuralism: political fatalism, moral emptiness, and neutrality. This sounds paradoxical, since constructivism was intended to lay these fears to rest for once and for all. The paradox becomes comprehensible, however, as soon as constructivism goes radical, and brings back agency not only to humans but to nonhumans as well. This radical, posthumanist variant of constructivism is on poor terms with (human) constructivism as the antipode to structuralism. Reason enough for some authors to be wary of the posthumanism of radical symmetry.

But not all of the contributors to this volume share these reservations. Kockelkoren and Verbeek, for example, employ the notion of radical symmetry in a refined analysis of technical mediation – of different ways of being-in-the-world, to put it in their (post-) phenomenologically inspired words. And Stemerding and Nelis use this very notion for an analysis of how subjects and responsibilities are constituted in new emerging practices of screening in the field of cancer genetics, thus relativising prevailing ethical principles like autonomy, freedom of choice and informed consent. Popkema and Harbers, finally, elaborate radical constructivism's posthumanist flavour precisely to rethink our traditional conceptions of politics and normativity instead of reverting to them, as Oudshoorn et al. seem to suggest.

In summary, all the contributions to this volume in some way deal with the question of how radical our radical constructivism should be – both sociologically (agency versus structure) and philosophically (agency of humans only or of nonhumans as well)? The first part of the question appears to be less controversial than the second part. Though some authors warn us not to neglect structurally induced constraints and asymmetries, nobody rejects the hard core of constructivism. The second, nonhuman agency part of radical constructivism is much more contested, not in the least because normative issues explicitly enter the stage here. Are we only talking about the social agency of nonhumans, which is accepted by all of the authors, or about their moral agency as well? The latter is explicitly rejected by some authors, reserving normative critique and moral judgement for human actors exclusively. Others, denying this human(istic) exclusivity with regard to responsibility, morality and normativity, are confronted with a new problem: if normative actorship for nonhumans is accepted, what then could still be meant by moral agency and responsibility? What are the consequences of nonhuman moral agency for (the possibility of) normative judgements and political interventions, i.e., for politically inspired criticism and action? As was said in the introduction to this volume, if science, technology and society, i.e., cognitions, artifacts, socialities, and moralities co-develop and are thus mutually dependent and immanent, how then can we critically evaluate this co-development? Is it in any way possible to reconcile radical immanence, including moral rules and normative judgements, with a critical stance? Or would that require a shift in our very conception of critique, normativity and politics?

Without wishing to claim a definitive solution, which would in any case be at odds with the basic constructivist tenor of this volume, I will approach this persistent issue via a brief contribution to the ongoing debate about the underdeveloped critical and political potential of science and technology studies – for that matter slightly changing my own role, from editor of the volume, who situates the various contributions, to a more independent author, who reflects upon the conceptual and normative consequences of those contributions.

## Normativity in Science and Technology Studies

Science and Technology Studies (STS) have often been accused of a lack of normativity. First, on the *epistemological* level, by normative/rationalist philosophers of science. With the empirical turn, these critics argued, every prescriptive, normative ambition of classical science theory was abandoned. This accusation was countered within the STS field by a change in the very concept of science – from a body of knowledge representing a world-out-there, to materially embodied practices constitutive of new worlds; i.e., from a propositional view on science to a performative view, from representation to intervention. Second, a similar accusation was made on the *political* level, now by normative political philosophers and advocates of the former Science & Society movement. They argued that by restricting itself to description, STS had foregone any hope of retaining its original critical, normative orientation. While the first accusation concerns normativity in matters of truth, the second concerns normativity in matters of justice. The first is about good knowledge, the second about the good life. The substance differs, but both accusations touch upon a common issue of how to be normative while also being empirical.

Is it possible to counter the second accusation in the same way as the first one – i.e., by reconsidering our very notion of politics in analogy to the earlier reconceptualisation of "science"? Bruno Latour (1995[b], 35) seems to suggest this course in response to Swierstra's (1995) observations about the normative deficit of ANT in particular and STS in general: "What students of science and technology have shown for objectivity – that its power is in no way diminished when it is redivided, localised, materialised, even though it is no longer seated in certain methodical minds – still needs to be done for morality. What would happen were we to relocalise, rematerialise and redivide morality just as radically as we have objectivity?" Let me briefly reconstruct the first, epistemological encounter, in order to find out what we can learn from it for the second, political one.

### *Normativity and epistemology*

Once upon a time, the philosophy of science was a normative enterprise, formulating rules for good science. With these prescriptive rules at hand, scientists' (theory) choices could be legitimised or criticised. Philosophy of science is thus shaped as a justifying project – the context of justification being its principle playing field; reasons and reasoning its subject of analyses. In this sense, normative philosophy of science is assumed to take on a first-person perspective which deals with how to improve and rationalise choices and decisions.

With the empirical turn in science studies, the theory of science disavowed this normative self-esteem. STS takes itself primarily as an empirical-analytical, that is a descriptive and explanatory enterprise – whether historical, sociological, or ethnographic/anthropological. Based on the original principle of symmetry (explain true and false beliefs in the same way), the sociology of scientific knowledge (SSK) – especially in the Strong Programme's causally oriented variant – primarily wants to describe and to explain, rather than to improve the development of science. In this sense SSK takes a third-person perspective, which asks what are the causes for acceptance or rejection of truth claims.

Not surprisingly, the empirical turn, thus interpreted, has always been accompanied by the accusation of forfeiting philosophers' of science original normative questions. SSK in particular, and STS in general, is widely regarded as being normatively crippled. Critics aver that its principle of symmetry and its descriptive, causally explanatory, third-person perspective prevent it from taking up the normative challenge.[4] Leaving aside all the subtleties of this supposed contradiction[5], the bottom line of the picture is a normative philosophy of science versus an empirical sociology of science, cognitive reasons versus social causes, science either as representation or as construction; either realism or relativism, either rationality or power. However different these positions are, they are at the same time also mutually condemned to each other. Both depend on the epistemological subject/object-scheme, on the separation between world and word, to phrase it in postlinguistic turn's terminology. While the philosopher of science weighs the cognitive reasons for the selection of truth claims, the sociologist of science explores the social mechanisms at work in this selection process. And ne'er the twain shall meet, precisely because they share the same dualistic epistemological vocabulary.

At least two paths lead out of this conceptual prison. The first one proceeds on the level of language and follows Wittgenstein's (1953) basic idea of the internal relation of rule and action – in epistemological terms: the internal relation between word and world. Kuhn (1970), for example, argued that a paradigm shift not only changes the perspective of a scientific community on the world, but this community's world itself, too. Consequently, there is no (epistemological) God's eye view, no rock bottom, no transcendence, no meta-reflexivity, only immanence and infra-reflexivity.[6] We live in the destiny of *das immer schon der Sprache* (Kamlah and Lorenzen 1973, 14).[7] Though attractive and effective in its critique of traditional representational epistemology, this linguistic-semiotic escape from the subject/object distinction is not without a new risk where its logocentric inclination, reducing everything to text, can easily lead to idealism, indeed to theology. "*In the beginning was the Word.... Through the Word all things were made; without him nothing was made that has been made*". (John 1:1-3)

The second way out of the epistemological prison also embraces the principle of immanence (of subject and object, word and world), but avoids the ghost of idealism. By means of its principle of radical symmetry, analytically equating humans and nonhumans, actor-network theory, for example, reconstructs the development of science not in terms of languages but in terms of hybrid collectives. Instead of a world-representing body of knowledge, science is conceptualised as a world making practice – not in the linguistic impregnated sense of Goodman (1978), but as a materially embodied practice.[8] Science is portrayed here as a Foucauldian *discours* – an ongoing practice; not as a Habermasian *Diskurs* – a communicative interruption of practice. The traditional opposition between realism (*das immer schon der Welt*) and idealism (*das immer schon der Sprache*) is dissolved here into a praxeological view on science: we live in the destiny of *das immer schon der Praxis*, in which word and world, subject and object, culture and nature, humans and nonhumans are mutually constituted. In this conception of science, representation is itself an intervention, and conversely, interventions create new forms and regimes of representation.[9]

This second way out allows us to talk frankly about realism again – not in the traditional, epistemological/representational sense but in a pragmatic sense, as phrased in the famous Thomas theorem: *If men define situations as real, they are real in their consequences.*[10] This kind of realism holds for social facts, and no less for natural facts. Even God exists in this conception of realism as long as people define God as real, He is real in His consequences. "A little relativism takes one away from realism; a lot brings one back," Latour (1988[b],173) said, later calling this position *historical or realistic realism.*[11] Reality is now not taken as a pregiven, transcendent and ahistorical world-out-there, but as an historical achievement, as an immanent product of ongoing practices. Also, rationalism is now allowed to re-enter the stage – not as a transcendental philosophy of Reason, but again as an immanent, historical achievement. It involves rational rules not taken as conditional for (scientific) knowledge production, but as part of that very production process, entailing a shared language game, a common form of life. Paraphrasing Bar-Hillel, we could summarise this view by saying that science is indeed a rational enterprise, but only given "*some suitable communicative situation*".[12] The core business of STS would then be to describe, to analyse, and sometimes to debunk this "suitable communicative situation". Of which heterogeneous elements is it constituted? What does it allow and what does it forbid us to think, to say, to do, to feel? What is included and what is excluded? And, as Star (1991) asked: *Cui bono*? These issues are not normative in the justificational meaning of the word, but neither are they normatively neutral, simply to be tackled by empirical means.

The accusation of STS's lack of normativity is based on a traditional view of science as a neutral, empirical-analytical enterprise and of a philosophy of science as a normative, judgemental (meta-)activity, i.e., on the dichotomy between facts and values, between description and prescription. But STS does not recognise this dichotomy. Taking the notion of immanence seriously, also in a reflexive sense, STS is neither *de*scriptive nor *pre*scriptive, since both options presuppose an outsider's position – either as a detached analyst, or as an involved, but no less exclusive judge. Just like scientific research in general, STS in particular could better be labeled as *re*scriptive – indeed *re*-constructing developments in science, technology and society. That is not a neutral and innocent activity, but neither is it a rule-based, normative affair. Infra-normativity is at stake here, an immanent, first-order praxis; not meta-normativity, a transcendent, second-order phenomenon.[13]

### *Normativity and politics*

Even though this redefinition of normativity within the context of epistemology will be accepted broadly, empirical STS in general, and ANT in particular, are still accused of a lack of normativity – now in the context of politics. The argument goes like this: if indeed science, including STS, is a matter of re-scription, and thus of "politics, pursued by other means", as Latour (1983) framed it, how then can we legitimise this kind of knowledge-politics? What is good and what is bad politics here? On which normative grounds can we say something about justice, about the good life in a techno-scientific culture? STS, according to these critics, doesn't have an answer to this politically (instead of epistemologically) normative question.[14,15]

Ignoring the subtleties and internal differences within this generic diagnosis, we can conclude that the therapy generally comes down to pleas for democratisation of science and technology – under such different banners as social learning (Wynne 1992), democratisation of technological culture (Bijker 1995[b]), citizen science (Irwin 1995), or simply democracy and technology (Sclove 1995).[16] Either implicitly or explicitly, these suggestions are grounded in a conception of what is called within political philosophy *deliberative*, *communicative* or *discursive democracy*.[17] As discussed elsewhere,[18] this conception of democracy is unfortunately burdened with several problems. In emphasising the formal rights to participate, for example, it tends to disregard substantial differences – differences in power as well as differences in expertise.[19] Or, to mention one more criticism, the theory of deliberative democracy is rather optimistic about the will of both experts and laymen to learn and participate. As if everybody wants to deliberate about everything all the time. According to the normative commitments of deliberative democracy, this should in fact be assumed as a moral responsibility by citizens. But that denies the human right to political laziness – a right so elegantly respected in systems of *indirect, representational* democracy, delegating our political duties to elected political professionals for a couple of years. Some of these problems, especially those related to the constraints of time, place and numbers (not everybody can have a say everywhere and everytime on any subject), can be more or less successfully resolved within the framework of deliberative democracy.[20] But taking into account what is said in this volume about co-production and nonhuman agency, this very framework itself is quite contestable – empirically as well as analytically.

The thesis of the co-production of science, technology and society, as was argued, implies a denial of the autonomy of either knowledge, power or morality. Cognitions, technological artifacts, social relations and moral rules co-develop. Thus, science and technology are saturated with socialities and moralities.[21] Knowledge and artifacts embody politics, as the contributions to this volume have shown time and again, acknowledging nonhuman agency anyway – either social agency or even moral agency. This diagnosis affected our views on science and technology, but should have consequences for our views on politics as well – both topologically and substantially. Where is politics? In many more places than traditional political philosophy supposes it might be found, i.e., within the nation-state's political system. Politics is displaced, Beck (1997) argued convincingly – not only to more or less globalised, transnational levels, but also to subnational levels like the courts, schools and hospitals, to bureaucracy, and, especially important in the present context, to the laboratory and the drawing table. At all these places we find "sub-politics", i.e., forms of politics not democratically guaranteed as in the traditional political system. And what is politics in these new contexts? Although the question cannot be answered in a generic sense, Beck argues that the displacement of politics requires nothing less than a reinvention of politics. In light of the contributions to this volume, we can at least conclude that politics is more than the deliberative tradition in political philosophy it wants to be – the democratic, discursive formation of political will.[22] Especially in the sub-political field of science and technology, as we have seen, politics is not so much a matter of deliberation and justification, as of materially embodied practices of world making.[23] These empirical findings inevitably have analytical consequences.

Normative political philosophy, like the normative philosophy of science, uses a restricted conception of normativity where normativity is a justification of choices, the weighing of reasons for and against a course of action. Normativity, then, is about conscious rule-following, presupposing a split between actions and practices on the one hand and deliberation about and justification of those actions and practices on the other hand. Again, normativity is perceived as a second-order matter, a meta-activity. The final source of normativity, Korsgaard (1996) argues in line with Kant, is our own autonomy. The principle of radical symmetry, De Vries (2001) argues, has been of major importance for descriptive purposes, i.e., for the replacement of a normative, epistemological vocabulary of scientific representation by a descriptive, anthropological vocabulary of construction and co-production. But this principle, he continues, also reverting to Kant, is inadequate when we switch to normative, political questions. Then he wants us to again produce an asymmetry between humans and nonhumans, between reasons and causes, between systems of rules and laws on regularities. Normativity, he argues, is an exclusively human affair. The argument is not convincing, however, since it is tautological. Only as long as De Vries and Korsgaard, joined by many other normative philosophers[24], define normativity as a rational enterprise, grounded on some conception of human autonomy or – less ambitiously – on some idea of human uniqueness, only then can human beings have a monopoly on normativity and moral agency. That is, as long as normativity, in line with humanism, is equated with legitimation and justification, i.e., with second-order deliberation about how and why to follow which rules. Only then can humans rule the waves. But that is a ruling by definition, inspired by a humanistic political philosophy aimed at normative justifications and critical evaluations – an honourable tradition, but with apparent shortcomings in practical, especially socio-technical contexts.

Induced by its own a priori's, other meanings of normativity are excluded beforehand. For example, De Vries and Korsgaard's second-order definition of normativity fails to appreciate first-order normative problems. As with the rationalist, rule-based view on science, Bar-Hillel's problem of the translation of indexicalities into non-indexicalities pops up again: if we want to pass a normative judgement on a specific action or a state of affairs, how can we decide to what kind of normative rule-system this action or state of affairs belongs? When, where and under which conditions is it *suitable* to put this *situated* action or state of affairs under the regime of a (which?) *non-situated* rule system – presupposing that we already know how to define the very situation?

In practical contexts this is often exactly the problem: how to define the situation? and accordingly, how to decide which rules are relevant and applicable? It is not legitimation and justification by rules that is on the normative agenda then, but the very construction of a *suitable communicative situation* without which rule-following becomes impossible – a shared language game, a common form of life, Wittgenstein would say; a proper socio-technical network of humans and nonhumans, to put it in STS terms. Surely, normative evaluation hinges on (good) rules, but at least as much on agreed-upon conditions for the application of those rules in the specific context to be evaluated. Creating these conditions, again, is neither a matter of description nor of prescription. It is a matter of rescription and reconstruction in order to make rule-based evaluations possible in the first place.[25] This kind of (re)constructive normativity-from-within *preceeds* any evaluative-judgemental normativity-from-the-outside. Only after this immanent, first-order construction work is done can a second-order, transcendent judgement be passed.

## Conclusion

Just as on the epistemological level, normativity on the political level is not only a matter of justification, deliberation and legitimation, but also, and even necessarily, a matter of (re-)constructing and deconstructing "suitable communicative situations", of making and unmaking different worlds – worlds which make certain sorts of deliberations possible, and others impossible. In the laboratories and on the drawing tables of our technological culture, as many case studies have shown, we do not come across free deliberations about scientific statements or about the efficiency of artifacts, let alone about moral rules defining the good life. Truth, efficiency and, by implication, the good life are not passively deliberated here, but actively created, constructed-in-practice, by using heterogeneous means – from ideologies to technologies, from ideas and ideals to artifacts and standards. Here, normative politics is neither solely a second-order phenomenon nor an exclusively human affair. In the context of socio-technical developments, politics is much more a matter of heterogeneous design and experimentation than of rule-based, moral deliberation and justification.[26]

Correspondingly, in this context democracy could be better interpreted as the proliferation of practices than as the proliferation of ideas. In the sub-political field of science and technology, politics and normativity are materially incorporated, i.e., built into the very process of making and unmaking of different socio-technical worlds. This reinvention of politics runs parallel to a reinvention of democracy, which implies keeping open as many worlds as possible. Democratic politics in a technological culture requires not so much an extension of participation in public deliberations, but a proliferation of rivalling socio-technical networks. Not closing off existing worlds by moral regulation, but opening up new worlds via heterogeneous (cognitive, technical, social, political and moral) experimentation – that is what is meant here by the democratisation of science and technology.[27]

To face down the accusation of being normatively crippled, STS should not go back to traditional ideas about normativity, politics, and deliberative democracy. That would mean a step backwards, ignoring achieved insights into the co-production of science, technology and society, about the heterogeneity of collectives, the agency of nonhumans, and the material embodiment of sociality and morality. These hard-won lessons, learned in the process of diagnosing our technological culture, should not be discarded as a basis for therapy. On the contrary, it would behoove us to take two steps forward, exploring other, less idealistic and humanistic conceptions and practices of politics and democracy, acknowledging that normativity and morality are incorporated into technological artifacts, rather than being merely regulative for them. Political materials deserve material politics.

## Notes

1 The notion of co-production thus contradicts, e.g., Popper's three-worlds theory, granting autonomy to the third world of cognitions (Popper 1972), Weber's principle of *Wertfreiheit*, separating politics from science (Weber 1973), and Kant's ideas about the autonomy of the moral agent (Kant 1974).

2 Technological determinism can take both an optimistic and a pessimistic form, i.e., a good (p.r.) story about progress and reason, and a bad story about alienation and dehumanisation. See the Introduction to this volume. In both cases, technology determines the fate of humanity.

3 These critical remarks concern the traditional sociological issue of agency and structure – not the issue of radical symmetry between humans and nonhumans. Though both issues are often mixed together, as in the Oudshoorn et al. contribution, it is useful for the sake of the argument to maintain the distinction.

4 See, for example, Laudan (1981) and subsequent discussions in *Philosophy of the Social Sciences 11*, 1981 and *12*, 1982. See also the "Responses and Reply" sections in *Social Studies of Science*, *11*, 1981 and *12*, 1982 about epistemology, relativism, and the empirical turn in philosophy of science. Similar issues were discussed earlier between Popper (and Lakatos) and Kuhn (and Feyerabend); see Lakatos and Musgrave (1970).

5 What, for example, remains of the philosophy of science's first-person perspective once it defines itself as "the highest court of rationality", overruling scientists' own reasons for theory-choice? The perspective, then, is still first-person oriented, but the verdict is given *ex cathedra*. Or, what to make of all those variants of SSK not accepting the Strong Programme's principle of causality, i.e., its naturalism and scientism, thus showing much more esteem for mutual dependencies between (third-person) scientific perspectives and (first-person) actor-perspectives?

6 Meta-reflexivity refers to reflexivity either from above (the all-seeing eye) or from below (grounding principles); infra-reflexivity always comes from within. Meta-reflexivity is a second-order activity; infra-reflexivity stays first-order. The distinction between meta- and infra-reflexivity was introduced by Latour (1988[b]). For similar ideas about outsider and insider positions, see also Haraway (1991) on "situated knowledges" and Harding (1991) on "outsiders within".

7 See also Lynch (1992) for the vital importance of Wittgenstein's philosophy for science studies – both epistemologically (the internal relation between meaning and practice, word and world) and sociologically (the "in-situ-atedness" of agency and structure).

8 See Pickering (1992); in particular the contribution of Callon and Latour (1992).

9 See also Hacking (1983, 2002) or Pickering (1995).

10 Take note of the addition "in their consequences". Situations do not become real due to the definition as such, but to the consequences of this definition in terms of concrete actions. Or, even better : these actions *embody* the definition. Without this addendum Thomas's theorema would only be a reiteration of idealism.

11 Latour (1996[c]) and (1999[a]), respectively.

12 The translation of indexical expression, i.e., statements using indexical words like "I", "me", and "here", into non-indexical expressions, Bar-Hillel (1954) argued, requires a shared language, a shared set of meanings, a shared practice – or, in his words "some suitable communicative situation".

13 The notion of rescription refers, obviously, to the performative effects, much more than to the propositional (representational) content of language where each rescription of a situation implies a redefinition and thus a remaking of that situation. Consequently, a rescription is more than a re-description, i.e., a new description of an unchanged reality. Rescriptions do actively intervene into realities and therefore are not normatively neutral. On the other hand, rescriptions are not normative in the traditional, judgemental sense either. Rescription is not a second-order, justificational activity from the outside, but a first-order, participatory activity from within. Rescription does not suppose an outsider's position – neither in the descriptive respect (representation) nor in the prescriptive respect (legitimation). Compare Rorty (1983) about a hermeneutic, edifying instead of judging and criticising philosophy, and Latour (1988[a], 1996[d], 2004) about the exhaustion of the critical style.

14 See Scott, Richards and Martin (1990), Radder (1992, 1998), Martin (1993), Winner (1993), Ashmore and Richards (1996), and subsequent discussions in *Science, Technology, & Human Values* and in *Social Studies of Science.* See also special issues of the Dutch STS journal, *Kennis & Methode* on facts and values (Pels and De Vries 1990) and on knowledge and politics (Aerts and Hagendijk 1992). For a recent contribution to this debate about the politics of STS, see Woodhouse et al. (2002).

15 On the other hand, as soon as STS tries to become normatively and politically relevant, for example in feminist studies of technology, these studies are criticised for their supposed 'failures of nerve', i.e., for residues of essentialism, due to an insufficiently radical constructivist critique of technology – see Grint and Woolgar (1995). Radical constructivism and political impact once again seem to be at odds. Fortunately, however, even though Grint and Woolgar have a point, there are exceptions to their rule. Van der Ploeg (2001) is every inch a normatively relevant, feminist study of reproductive technologies, without any failure of nerve and in all respects "postessentialist", hence fulfilling Grint and Woolgar's stringent requirements. See Harbers (2003).

16 See also Von Schomberg (1999), Feenberg (1999), and Kleinman (2000).

17 See, e.g., Bohman and Rehg (1997), Benhabib (1996), Habermas (1996), Dryzek (1990, 2000), Fishkin (1991), and Elster (1998).

18 See, e.g., several contributions to Benhabib (1996) and De Wilde (1997).

19 Concerning differences in expertise, see also Collins and Evans (2002). They too, criticise the undertone of unlimited participation in pleas for democratisation of science and technology, but their alternative, a re-articulation of boundaries between included experts and excluded laymen, goes the opposite way to the one advocated here. Their proposal is based on a rather contestable re-introduction of the demarcation between technical and political questions, the first being open to experts only (though of different kinds), while the second would be accessible for all civilians. Moreover, though they want to formulate normative criteria for the limitation of participation, their proposal remains within this very paradigm of democracy as participative deliberation. It is not the world making capacity of science and technology that is their problem, but the question of who should have a say (and especially who not) in the settlement of propositions *about* the world – thus falling back on a propositional view on science, as Wynne (2003) argued.

20 E.g., Goodin (2000).

21 Karin Knorr Cetina's (1997) notion of "object-centred sociality" can thus be extended with "object-centred morality" – not only sociality incorporated, but morality and politics as well. See also Latour (2002).

22 Since pleas for democratisation of science and technology almost exlusively are based on this deliberative tradition (for an exception, see De Vries 2002), other currents in politicial philosophy will be left aside, e.g., the liberal-democratic no-

tion of politics as a system of checks and balances. Whether this view on politics is compatible (or not) with radical constructivism's posthumanism would need a separate argumentation.

23 See the Popkema and Harbers contribution; but also see Elzen about niches for socio-technical experiments; Disco about experiments in high-energy physics; and Stemerding and Nelis about technologically mediated production of new subject-positions in medical health care.

24 See, for example, Dworkin (1977). Though Dworkin acknowledges the immamency of rules, he still reproduces the idea of second-order normativity by distinguishing network-dependent rules from network-independent principles.

25 This argument in favour of normativity-from-within thus runs parallel for both epistemology and politics. While on the epistemological level rescription of situations is sometimes needed in order to make possible objective descriptions of external realities, on the political level, rescriptions of situations are sometimes needed to make possible prescriptive judgements based on external norms. Wynne's (1996) study of risk perception in the Chernobyl case is a well-known example on the first level; the analyses of Harbers et al. (2002) of (criteria for) the good care of elderly people suffering from dementia is an example on the second level.

26 For politics-going-ontological, see also Mol (1999, 2002).

27 Compare Barry (2001) and Gomart and Hajer (2003) for similar thoughts.

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