THE INFORMATIZATION OF THE WORLDVIEW

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Abstract

The development of information and communication technology in the second half of the twentieth century in crucial respects resembles the development of mechanics in the sixteenth and seventeenth century as it has been described by Dijksterhuis in his study *The Mechanization of the World Picture* (first published in 1950). In both cases specific technological developments not only lead to important changes in the natural and human sciences, but also profoundly affect culture as a whole and eventually result in a fundamental change in worldview. In this article the author attempts to elucidate the present informatization of the worldview in a twofold way. First, against the background of Dijksterhuis' analysis of the concept of *mēchanē*, a clarification is given of the concept of information, which has become central to many sciences in the last decades. It is argued that much of the confusion and misuse that surrounds the application of this concept can be reduced by making a careful distinction between the pragmatic, semantic and syntactic dimensions of information. Second, on basis of this clarification, the author discusses the transformation from a mechanistic to an informationistic worldview. While the mechanistic worldview is characterized by the postulates of analysability, lawfulness and controllability, the informationistic worldview is characterized by the postulates of synthetizability, programmability and manipulability. It is argued that although the informationistic worldview in some respects (for instance in its mathematical orientation) is clearly a continuation of the mechanistic worldview, in other respects it fundamentally alters human experience and the evaluation of, and association with, reality.

Keywords

information, ontology, mechanization and informatization of the worldview,

INTRODUCTION

In the beginning there was information. The word came later.

(Dretske 1981: vii)

In his book *The Mechanization of the World Picture*, originally published in 1950 (reprinted in 1986), the scientific historian E.J. Dijksterhuis described how in the sixteenth and seventeenth centuries the introduction of scientific experimentation and a mathematical description of inorganic nature gave a completely new aspect to the natural sciences. The consequences of this scientific revolution did not remain confined to the natural sciences: the new method also had an influence on important elements of the human and cultural sciences. Furthermore, the natural sciences and the machine technology linked closely to them made a crucial contribution to the industrialization of western society. The title of Dijksterhuis' book succinctly expresses the author's conviction that the introduction of the new method eventually led to a transformation in our concept of the reality of humankind and of the world. For this reason, as Dijksterhuis observed in the introduction to his book,

> the mechanization of physical science has become much more than an internal question of method in natural science; it is a matter that affects the history of culture as a whole, and on this account it deserves the attention of students outside the scientific world.
>
> (Dijksterhuis 1986: 3)

The introduction of the electronic computer fifty years ago,[1] prompted a development which in many respects is reminiscent of the transformation Dijksterhuis described. In the case of information technology, too, we are concerned with a development which has its origins in the world of the exact sciences and technology, which has far-reaching consequences for the other sciences and for society and culture as a whole, and which, eventually, also fundamentally affects our view of the world. In this article I will attempt, from a philosophical perspective, to shed a little light on this development, a development which, alluding to Dijksterhuis' study, we might designate as the informatization of the worldview.

INFORMATIZATION

Few would deny that information technology has fundamentally changed the complexion of our world. Obviously, we must not only consider the physical presence of the many millions of computers in the world we live in, but also the fact that information technology has a profound influence on existing organizational structures and balances of power and brings about fundamental changes in the production, distribution and consumption of goods, knowledge and culture (Castells 1996, 1997a, 1997b).[2] When I speak of an informatization of the worldview, however, I do not only have these developments in mind; I am thinking particularly of the no less fundamental implications that information technology has for our perception and interpretation of reality.

Computers increasingly mediate human experience of, and association with, physical and cultural reality. The images and sounds with which newspapers, magazines, books, radio, television and films deluge us are processed, or even generated, with the aid of computers with ever increasing frequency (cf. De Mul 1997). Smaller and smaller processors in everyday appliances such as microwave ovens, washing machines and cars regulate our association with the things around us. Furthermore, computers linked in global networks are functioning increasingly as environments in which human communication and communion take place (cf. Holmes 1997; Jones 1995, 1997).

The computer has also become indispensable in scientific research. Here, we must not only consider office automation and the rapid developments in the provision of scientific information, but also the fact that research into reality carried out within the natural and cultural sciences is increasingly presented as a set of computer-generated data. Computers visualize and simulate phenomena which are invisible to the human eye or difficult or inaccessible to human understanding (Aukstakalnis and Blatner 1992: 227–35), are deployed in the statistical processing of data, furnish mathematical proofs[3] and make new methods of reading, interpreting and writing possible (Bolter 1991; Joyce 1995; Landow 1992, 1994; Lanham 1993).

It is not surprising that the mass deployment of computers in scientific practice has also affected theory. The concept 'information' has become central to many sciences. In the first place we can consider disciplines such as cybernetics, information theory and computer science (which have developed simultaneously with the computer and which are usually mathematically orientated and have information or information processing as their objective), as well as specialized variants of these, such as the medical, economic, social administration, juridical and alpha-informatics. In *Mind Tools: The Mathematics of Information* , Rudy Rucker argues that information is more than merely a new subject for mathematical research. According to him the concept 'information' is a fundamental one, which lies at the heart of all the subdisciplines within mathematics. Mathematics, he reasons, can indeed be understood as a collection of formal techniques – algorithms – to transform given information into new information (Rucker 1988: 29–30). The concept 'information' is also found more and more in the foreground of the natural sciences. Physical, chemical and biological systems are regarded as information-processing systems. In physics the statistical approach to thermodynamics and quantum mechanics in particular has made information a crucial concept. In biology, too, the concept 'information' has become a central one. The molecular biologist Eigen states:

> At the end of the 20th century, we are conscious that in many different branches of biology analogous questions are being formulated. These can be commonly phrased as 'How is information generated?'. This is true for the process of evolution at the molecular level, for the process of differentiation at the cellular level and equally for the process of thought in a network of nerve cells. Still more exciting is the appreciation that nature apparently uses similar fundamental principles in quite different technical implementations in molecular genetics, the immune system and the central nervous system.... The legacy of biological research in this century will be a deep understanding of information-creating processes in the living world. Perhaps this entails an answer to the question 'What is life?'
>
> (Eigen 1995: 13–4)

Eigen's reference to nerve cells suggests that the mind can also be understood in terms of information. On the basis of this hypothesis a new discipline, known as cognitive science, has been developed over the last decades. In cognitive science, the analysis of the human mind, which was previously the domain of psychology, linguistics, philosophy, the computer sciences and the neurological sciences, has been brought under the common denominator of the concept 'information'. In the words of Neill Stillings: 'Cognitive scientists view the human mind as a complex system that receives, stores, retrieves, transforms, and transmits information' (Stillings *et al*. 1995: 1). It is also not surprising that the informatization of society and culture has resulted in the concept 'information' being placed high on the agenda of the social sciences and the humanities.

It is therefore not only in a literal sense that our view of the world has been transformed by information technology. In a metaphorical sense, too, we can speak of an informatization of the worldview. The omnipresence of information technology seduces us into thinking that everything can be regarded in terms of information and that in the final analysis the world is built up of information. Keith Devlin explains this idea in his book *Logic and Information* (in so doing, he actually only reiterates what has been repeatedly asserted in various ways since Wiener's pioneering work, published in 1948, in the field of cybernetics): 'Perhaps *information* should be regarded as (or maybe *is*) a basic property of the universe, alongside matter and energy (and being ultimately interconvertible with them)' (Devlin 1991: 2). Rucker makes a similar observation:

> I think the real issue was that the computer revolution forced people to begin viewing the world in a new way. The new worldview that computers have spread is this: everything is information. It is now considered reasonable to say that, at the deepest, most fundamental level, our world is made of information.
>
> (Rucker 1988: 31)

Without doubt this is a challenging proposition. When, however, we seek to answer the question of what information actually *is*, there appears to be a considerable amount of confusion surrounding the concept and the answer is not easy to find. The concept 'information' is used to denote a whole series of different – and often rather diverse – things. The precise correspondence, for example, of human communication, the reproduction of DNA molecules in a cell and the transfer of electronic signals in a computer, is not immediately apparent. Furthermore, in many instances the concept 'information' is used without any attempt being made to define it.[4] When an attempt *is* made, the given definitions are often vague or ambiguous, and even if they do possess a certain measure of clarity, not infrequently they contradict each other. All this leads Theodor Roszak to lament in *The Cult of Information* that:

> Information has taken on the quality of that impalpable, invisible, but plaudit-winning silk from which the emperor's ethereal gown was supposedly spun. The word has received ambitious, global definitions that make it all good things to all people. Words that come to mean everything may finally mean nothing; yet their very emptiness may allow them to be filled with a mesmerising glamour.
>
> (Roszak 1986: ix–x)

Sybille Friedrich goes as far as calling information a concept that belongs in the realm of myth and ideology, rather than in that of science (Kramer-Friedrich 1986: 23–5).

On the basis of criticism such as this, some suggest that it would be better to remove the concept 'information' from our vocabulary altogether (Woolley 1992: 70). Although – professionally inclined towards a certain scepticism – I have a good deal of sympathy with this criticism, nonetheless this solution seems to me to be rather too simple. There is, moreover, a danger of throwing out the baby with the bathwater, because the fascination and confusion surrounding the concept 'information' could also be seen as an indication that a new transformation of our worldview is taking place. Rudy Rucker, quoted earlier, makes a similar conjecture when he writes:

> the concept of information currently resists any really precise definition. Relative to information we are in a condition something like the condition of the seventeenth-century scientists regarding energy. We know there is an important concept here, a concept with many manifestations, but we do not yet know how to talk about it in exactly the right way.
>
> (Rucker 1988: 26–7)

I am aware that this quandary casts a threatening shadow on the attempt that I shall be making in the following argument, to contribute to the philosophical clarification of the meaning of the concept 'information', and to the process I have called the informatization of the worldview. All the more so because the widespread use of the concept forces the philosopher to enter various areas of science in which he can only speak with the authority of an informed layman. That I nonetheless hazard this attempt stems from my conviction that only an interdisciplinary dialogue can lead us to the desired clarification. As a philosopher, my contribution to this dialogue consists primarily of a clarification and explanation of the *ontological* dimension of the concept 'information'. In contrast to empirical propositions, philosophical statements have not so much a bearing on the factual characteristics of reality as on the presuppositions with which we approach reality in both everyday life and in scientific practice. In the present case this concerns the presuppositions which we already allow to guide us in our attempts to describe or understand the concept 'information', and in our association with that which, according to these presuppositions, counts as information.[5] What I wish to clarify, therefore, is the manner in which the concept 'information', and the information technology linked to it, affect the way we perceive, evaluate and respond to the world – in short, our *worldview*.[6]

A change is always a change with regard to something which has preceded it. In order to clarify the ontological dimension of the concept 'information', I shall compare the informatization of the worldview to the mechanization of the worldview, as described by Dijksterhuis. This conceptual counterpoint will make clear that while the informationistic worldview builds on the mechanistic, it also differs from it on a number of crucial points. Before going further into the concept 'information' and the informatization of the worldview I shall first give further consideration to Dijksterhuis' interpretation of the mechanization of the worldview.

THE MECHANISTIC WORLDVIEW

In everyday language the concept 'mechanization', which has its etymological roots in the Greek *mēchanē* (instrument), concerns the replacement of human or animal labour by machines. The related term 'mechanical' also primarily refers to that which takes place by means of instruments. In addition this adjective concerns mechanics or theoretical mechanical engineering, that section of physics concerned with the motion of material objects. The term 'mechanical' is also used to indicate activities carried out in an automatic or unthinking manner. The term then has a negative connotation and refers to the inanimateness that characterizes a machine.

When Dijksterhuis speaks of the 'mechanization of the world picture', the aspects of meaning mentioned do indeed play a role, but they acquire a more specific meaning which is linked to the development of classical physics in the period between the publication of Copernicus' *De Revolutionibus Orbium Coelestium* (1543) and Newton's *Philosophia Naturalis Principica Mathematica* (1687) (Dijksterhuis 1986: 287 f.). This is not to say that this gives the concept 'mechanization' an unequivocal meaning. In the epilogue of *The Mechanization of the World Picture* Dijksterhuis distinguishes various meanings, the three most important of which I will discuss.

In the first interpretation the mechanistic world picture is based on the premise that the physical universe is a great machine which, once it has been set in motion, by virtue of its construction performs the work for which it was called into existence (Dijksterhuis 1986: 496). In the early days of classical physics it was mechanical clockwork in particular that was put forward as an illustration of this notion. The ingenious mechanism of clocks such as that of the Minster in Strasbourg persuaded quite a few classical physicists to compare nature to a clockwork (Dijksterhuis 1986: 442 f.). According to Dijksterhuis, however, this view is incompatible with the basic idea of original *atomism* on which classical physics is based. According to this basic idea all processes taking place in the world are essentially absolutely irregular, purely accidental motions of immutable minute particles. Conversely, the conception of nature as an ingenious machine conjures up an image of a conscious and intelligent maker, who has constructed it and makes it work in order to achieve a particular object. Although the conception of nature as a complex machine played an important role in the mechanization of the worldview, according to Dijksterhuis it played hardly any meaningful role in the actual development of classical science. In the early days of classical physics, physicists primarily used this conception metaphorically in order to placate the ecclesiastical authorities who were somewhat suspicious of the atomistic way of looking at nature. According to Dijksterhuis, where teleological ideas did play a serious role in physics, as they did with Newton, they proved to be a dead end. Metaphors, however, are more than mere ornaments. They disclose reality in a particular way (cf. De Mul 1999a: Chapter 1). In this sense the machine metaphor also applies in the second interpretation of the term 'mechanization' distinguished by Dijksterhuis.

This second interpretation is also linked with the original meaning of 'instrument', but in this case it touches on the tendency of modern physics to search for hidden mechanisms behind those that can be perceived by the senses. The assumption is that these mechanisms:

> would be essentially of the same kind as the simple instruments which men have used from time immemorial to relieve their work, so that a skilful mechanical engineer would be able to imitate the real course of the events taking place in the microcosm in a mechanical model on a larger scale. The pursuit of this object was, and is, frequently looked upon as the really distinctive feature of classical science and the true meaning of the descriptive adjective 'mechanistic'.
>
> (Dijksterhuis 1986: 497)

Without doubt this concept has played an important role in the development of classical physics and, furthermore, suggests close links between the development of machine technology and classical physics.

According to Dijksterhuis, however, this view of mechanization does not completely conform to the actual development of physics. Namely, in this development concepts which had a much looser relationship with the fundamental concept 'instrument' quickly came to the fore. There is a certain irony in the fact that, as physics developed, Newton's concept of force (later substantialized to the concept of energy and rejected by supporters of the second meaning of the mechanistic world picture, such as Huygens and Leibniz, as essentially unmechanistic) came to be seen as the most characteristic feature of the mechanistic view.

The third meaning which, according to Dijksterhuis, can be attributed to the concept 'mechanization' is concerned with the way mechanics work. This way of working is *mathematical*, not only in the sense that mechanics makes use of mathematical methods in order to express in a shorter and more orderly manner what, if need be, could be expressed in the language of everyday speech, but also in the stronger sense that mechanics itself *is* a mathematics. The mechanization of the world picture in this third meaning, then, came about with the idea that 'nature has to be described in mathematical language and that it can only be understood by man to the extent that he can describe its workings in that language' (Dijksterhuis 1986: 497). From this perspective, modern physics, characterized by the theory of relativity and quantum mechanics, does not mean a radical break with the classical physics of Newton, but rather is a radicalization of it.

What ontological premises or postulates of the mechanistic worldview can now be drawn from the foregoing? In my view there are three. According to the *postulate of analysability*, reality can be analysed as a collection of elements which are separate from each other, and which can be determined logically and independently of each other. According to the *postulate of lawfulness*, these atomic elements are then brought together by means of laws which can be expressed in the form of a mathematical equation (cf. Boer 1980). The law of

Boyle and Gay-Lussac concerning gases can serve here as a simple but paradigmatic example. For a gas in a closed space the law 'pressure times volume divided by temperature is constant' (expressed by the formula $pV/T =$ constant) applies. Such expressed laws allow us to explain, predict and control phenomena. When, for example, the pressure of a constant volume of gas increases, then the cause must be sought in a rise in temperature. On the basis of the same law we can, moreover, predict that when we increase the temperature still further the pressure will further increase. It also follows from this that prediction is structurally equivalent to control. From the established law now follows the technical prescription: when you wish to increase the pressure of a constant volume of a gas, you must raise the temperature. Theoretical knowledge of mechanistic science – and this not only applies to natural sciences, but also to social and human sciences in so far as these aspire to causal knowledge – is therefore, in Duintjer's words: 'in the first place applied to the possibility of controlling, influencing and directing empirical phenomena.... Modern science is structurally equivalent to technology and in this sense a means of technical intervention' (Duintjer 1974: 37). Besides the postulates of analysability and lawfulness, the *postulate of controllability* can therefore be laid as the third cornerstone of the mechanistic worldview. Obviously this does not claim that striving for control is always successful. This is not only related to the fact that in many instances – when we are concerned with chaotic phenomena, for example – strict limitations are set on predictability, but also because interfering with nature often brings countless unintentional side-effects with it.

Notwithstanding these limitations, the triplet *explanation* , *prediction* and *control* have made a strong contribution to the spectacular success of the mechanistic sciences. They have played an important role in the modern project of the 'domestication of destiny'. The structural equivalence of mechanistic science and technological control also makes it clear that machine technology and the Industrial Revolution that stemmed from it were not a chance bonus from mechanistic science, but originated at the same time. Machine technology is usually interpreted as applied mechanical science. It would be just as valid, however, to interpret mechanical science as theoretical machine technology (cf. Mitcham 1986: 3).

FROM MACHINE TECHNOLOGY TO INFORMATION TECHNOLOGY

Machine technology, in comparison to instrument technology which preceded it, marked a new stage in the history of technology (cf. Gehlen 1957: 19; Habermas 1968: 337–8; Schmidt 1954). From an anthropological perspective, technology can be interpreted as a combination of natural forces according to a *design* devised by man. While in the case of instrument technology – the hammer can serve as an example here – this design is only implicitly given in the actions of the user of the tool, in the case of machine technology – the internal combustion engine, for example – the combination of natural forces is realized in the form of an independently functioning mechanism. The mechanical machine, as Maarten Coolen explains, is a *physical representation* of its design (Coolen 1992: 34). Here we once again encounter the concept 'information' that is central in my argument. When we call the machine 'a physical representation of a design', then we mean that the machine embodies *information* with regard to the required combination of natural forces. It is thus not the case that the machine processes this information itself. The machine is not less, but neither is it more, than a physical representation of this information.

This changes, however, in the third – and provisionally the last – stage in the development of technology. In this stage the machine itself handles the information. The industrial robot serves as an example of such an information-processing machine. Where the classical machine is a physical representation of a particular programme, such a robot is '*a mechanism that realizes the physical representation of each introduced programme as one of its possible operating procedures*. Through this the mathematical-logical structure of the programme acquires a physical execution' (Coolen 1992: 38–9). While the programme – the information regarding the required combination of natural forces – remains implicit in the classical machine, the information in the case of the information-processing machine is made explicit. Because this explication has a mathematical character and can therefore be seen as a mathematical object, it can be represented in the form of an unequivocal sign. For this reason the machine can be conceived as a *working sign* (Coolen 1992: 39). With the aid of physics, information-processing machines can be understood in as much as physical processes take place within them, but this is not sufficient. In order to understand them fully we must also consider them from the perspective of information.

What differentiates this approach to the problem in question from the dominant trends in cognitive science and the search for artificial intelligence is that it does not comprehend man from the standpoint of the information-processing machine or computer, but the other way round: the computer from man's standpoint.[7] In the anthropological approach to technology, its successive stages are conceived as external objectifications of successive stages of man's self-understanding (Coolen 1992: 250–71). The *technology of the instrument* was attuned to an association with the immediate lifeworld. Although instrument technology is based on natural laws, the implicit knowledge of those laws is not yet reflected. In contrast, in *machine technology* the required technical operations are an explicit part of the design. Here we find the objectification of a rational (self-)reflection in an external device. In *information-processing technology*, finally, the technical idea as such acquires externalization in a computer program. The industrial robot is able to translate information, as it is organized in a computer program, into a series of physical operations that it subsequently can perform.

We might also express this as follows: only when man, at the very least implicitly, understands himself as a creature that deals with information, is he able to objectify this insight – and as such to make it explicit – in an information-processing machine. Subsequently he can project this objectification back upon himself and interpret himself *explicitly* (though metaphorically) as an information-processing 'machine'.[8] This also opens the way to the development of an explicit *concept* of what information is.

THE CONCEPT 'INFORMATION'

Although it is clear in the foregoing that the concept 'information' (like so many concepts) has an anthropomorphic character, in my view this is only half the story. A brief glance at the history and everyday use of the concept 'information' shows that this not only refers to the thinking of the human *subject*, but also to the *object* of the information. The etymological roots of the concept lie in the Latin *informatio* and *forma*. The latter concept, in turn, is a translation of the Greek *eidos* (form), which in Plato and Aristotle refers to a fundamental characteristic of everything which exists, but also indicates that which human knowledge makes possible. In Aristotle the form is the opposite of the material, the potential aspect of the object, as that by which the object acquires its actual shape and is recognizable to man (Weizsäcker 1974: 343). Both the Latin *informatio* and the concepts in the modern languages which are derived from it contain this double connotation (cf. Schnelle 1976). In everyday use of language the concept 'information' denotes both a certain state of affairs in reality and the opportunity the receiver of the information obtains to gain a certain knowledge or insight into this state of affairs. When we say that a thermometer gives information about the temperature in the room, then this presupposes that there is also a recipient whose knowledge or insight is increased by this information and who can adapt their thoughts or actions on the basis of it.

If we interpret information in this way, we can also say that it is a *sign*. In semiotics, three dimensions with regard to the sign, which also appear to be relevant in the case of information, are generally distinguished. These concern the distinction between a *syntactic* dimension, which concerns the formal relationships between the signs; a *semantic* dimension, which concerns the designated function and the meaning of the sign, and a *pragmatic* dimension, which concerns the relationship between the sign and the *user* (cf. Hartshorne, Weiss and Burks 1931–1958; Morris 1938). With the aid of this distinction we can define information as a sign that (1) occurs with a certain probability or frequency within a sequence or arrangement of physical events, so that (2) a specific reference and therefore possibly meaning is ascribed to a recipient and (3) it contains the potential to modify the mental and/or physical actions or behaviour of the recipient in a particular way.[9] This definition gives us a criterion to distinguish the various aspects of meaning that the concept 'information' has in the various contexts of usage, and also allows us to articulate the individual nature of the informationistic worldview compared to the mechanistic. I shall illuminate this briefly on the basis of the three dimensions of the sign.

The definition of the *pragmatic* dimension leaves open the question as to whether the recipient is, for example, a human being, an animal, a plant or a machine. When we take only this dimension as a criterion then not only is man an information-processing creature, but this also applies to the amoeba, which adapts its behaviour on the basis of certain characteristics in its environment, and to the thermostat, which on the basis of temperature switches the central heating on or off. In this respect, even this simple device (in contrast to, for example, the thermometer which reads the temperature but does nothing with that 'information') belongs to the class of information processing entities. This even applies to simple molecules, the so-called replicators, which with the assistance of smaller molecules in their vicinity make copies of themselves.[10] Where in the mechanistic world picture a sharp dichotomy arises between matter and mind, or, problematically, mind is reduced to matter, then the informationistic line of approach opens up the prospect of common ground between matter and mind in which the differences between lifeless nature, living organisms and human intelligence can consequently be articulated.

The semantic distinction made between *reference* and *meaning* in the definition is of importance for this articulation. A sign generally refers to the world outside the sign. This reference can take place in different ways. It can, as in the case of the indexical sign, be determined causatively (for example, when we say that smoke is a sign of fire or an increase in temperature is a sign of fever), but it can also take place iconically, on the basis of an analogy (the way in which a painted portrait refers to the person portrayed) or symbolically, that is to say according to an arbitrary convention (for example, depending on the convention followed the woolly creature in the meadow is designated a 'sheep', 'mouton' or 'Schaf').

The meaning of a sign, however, does not correspond with the reference, but is also dependent on the relationship which it maintains with the other signs within the system in which it occurs.[11] The semantic value of information is dependent on the horizon of experience, or – speaking hermeneutically – the *world* of the user (cf. Heidegger 1979: 52–113). A symptom that provides the doctor with valuable information for the determination of a diagnosis can be meaningless, or have a very different meaning, to the patient. Depending on the recipient's horizon of experience the same information can give rise to different forms of knowledge and action.

On the basis of this twofold semantic criterion a distinction can be made between man and the lower organisms on the one hand, and between the lower organisms and the machine on the other.[12] While for humans a certain piece of information not only refers to a state of affairs in reality but also has a meaning in the context of their world, with plants and animals a piece of information appears to be primarily limited to the referential function, more especially to the indexical and – in the case of the higher primates – the iconical reference. With the machine, not only the meaning but also the reference appear to be completely absent. The thermostat mentioned earlier might control the temperature in the house with particular efficiency, but the 'information' has no meaning whatsoever to the thermostat (of course, it does for human users, assuming that they know the function of the thermostat). When we choose to reserve the adjective 'information-processing' for beings which possess a semantics, then even the most advanced computer cannot be termed an information-processing machine. Indeed strictly speaking the computer does nothing other than rearrange electronic signals in a mechanical manner according to rules which have no relationship to the meaning ascribed to these signals by the computer user.[13] This does not preclude in principle the possibility of information-processing machines in the sense mentioned, though. This possibility, however, could only be realized if we could find a way of at least implementing a semantic capacity at a referential level in the computer.

The notion that computers process information is nonetheless rooted in information theory and computer science, and this arises from the specific meaning – which differs from the everyday meaning – attributed to the concept ‘information’ in these disciplines. Namely, the definition of the concept ‘information’ in information theory is strictly limited to the *syntactic* dimension of the sign. Norbert Wiener, the founder of cybernetics, defined information in his work *Cybernetics, or Control and Communication in the Animal and the Machine* (1948; 3rd edn, 1961) as the probability of a specific signal appearing in a transfer of signals. Given a particular collection of signals, every element of that collection will appear with a specific probability. This probability determines how much information such an element carries. The lower the probability of an element appearing, the higher the informational value. The assertion that the rector of Erasmus University in Rotterdam is a professor has a high probability and therefore a low informational value. When I state that the present rector is Professor Akkermans the probability is lower, but precisely for this reason the informational value is higher.

Claude Shannon, who in *The Mathematical Theory of Communication* (1948; 4th edn, 1969) gave information theory the elegant mathematical formulation which has found general use in the field, unhesitatingly recognizes the restriction of this theory to the syntactic dimension:

> Frequently the messages have meaning; that is they refer to or are correlated according to some system with physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one selected from a set of possible messages. The system must be designed to operate for each possible selection, not just the one which will actually be chosen, since this is unknown at the time of design.
>
> (Shannon and Weaver 1969: 31)[14]

On the basis of this syntactic concept of information, Shannon was able to give mathematical definitions of the informational capacity of analogue and digital information channels, of the measure of noise and redundancy, and so on.

The mathematical formulation of information opened up the opportunity to relate it to physics. Both Wiener and Shannon link the concept ‘information’ with the notion of entropy in statistical mechanics. As Wiener puts it:

> The notion of the amount of information attaches itself very naturally to a classical notion in statistical mechanics: that of entropy. Just as the amount of information in an system is a measure of its degree of organization, so the entropy of a system is a measure of its degree of disorganization.
>
> (Wiener 1961: 18)[15]

Wiener defines information therefore as *negative* entropy. What leads to some confusion is that Shannon equates information with *positive* entropy. For Shannon the informational value is defined as the measure of freedom with regard to the selection of elements which exists in a communication process. The greater the freedom of choice, the greater the uncertainty and therefore the greater the entropy. In this sense, a page containing letters placed at random has greater informational value than a page from Kant's *Critique of Pure Reason*. Indeed, the choice we have in the selection of each succeeding element is greater in the case of an arbitrary series of symbols than in a natural language. Although from a semantic perspective this is at first sight a remarkable postulate, when we look closer there is nonetheless something to be said for it. Information overload, for example, not only has to do with the quantity of information, but more especially with the fact that the various and often conflicting messages increase our uncertainty about what is going on.[16] Despite the difference in interpretation of the relationship between information and entropy, it is clear that the syntactic dimension of information has to do with *form*, that is to say with a specific configuration of elements within a field of possibilities, and that this form makes the given configuration transferable and recognizable.

The mathematical form of information theory and the linkage of this theory with physics indicate that clear continuity exists between the mechanistic and the informationistic worldviews. This does not mean, however, that information can simply be converted into matter or energy. Earlier I quoted Devlin, who called information a basic property of the universe, in addition to matter and energy. Wiener also emphasized the different nature of information: 'Information is information, not matter or energy. No materialism which does not admit this can survive at the present day' (Wiener 1961: 132).

What is the basis for these claims? In the foregoing I observed that the mechanistic world picture is based on the postulate of lawfulness. That is to say that causal relationships within this worldview occupy a fundamental position. This is not the case within the informationistic worldview. Although in most instances a causal process between sender and receiver lies at the base of the transfer of information – because the information is carried by a series of electronic signals, for example – the informational relationship between sender and receiver does not correspond. Namely, the causal story tells the receiver nothing about the field of possibilities in which the signal appears. There are even conceivable situations in which complete information is transferred without there being any question of a causal relationship between sender and receiver. When, for example, I tune my television set to a particular channel, then the screen informs me what is to be seen on the screen of all the other television sets which are tuned to the same channel at that same moment. This information, however, is not transferred through a causal process between my television set and the other sets. On the other hand, countless causal processes exist which on the whole do not transfer information. When I look at the back of a playing card, though the card partially causes my sensory perception, it transfers no information as to which of the fifty-two playing cards the card in question is (Dretske 1981: 29).[17]

An analogue argument could be developed with regard to the relationship between information and energy. On the basis of this we can provisionally conclude that information has a different ontological status from matter and energy. It goes without saying that this does not exclude the possibility that sometimes a mathematical relationship between matter, energy and information might be discovered, just as the relationship between matter and energy was described in the theory of relativity.[18] Within the context of our present knowledge, however, we are concerned with entities with clearly distinct characteristics.

THE INFORMATIONISTIC WORLDVIEW

Against the background of the foregoing clarification of the concept 'information', in this final part of my argument I will attempt to formulate the similarities and differences between the mechanistic and informationistic worldviews. To do this I will take the three meanings of the mechanization of the worldview, as distinguished by Dijksterhuis, together with the three cornerstone postulates – analysability, lawfulness and controllability – as guiding principles.

The expression 'informatization of the worldview' can, in the first place, indicate the notion that the physical universe can literally be regarded as an information-processing machine. As Woolley puts it:

> The universe-as-computation is more than just a metaphor. If the laws of physics are mathematical, perhaps they are computable. Perhaps everything is in some mathematical relation to everything else. Since the universal Turing machine is capable of performing any arithmetical computation, then a Turing machine could, in principle, 'run' the universe. Put another way, perhaps the universe is really, not metaphorically, a Turing machine, a pattern of perpetual computation.
>
> (Woolley 1992: 78)

The view that the human brain is a computer which we encounter in the 'hard' sector of research into artificial intelligence, is a variant of this interpretation of the informationistic worldview. At first sight it appears an objection could be put forward to this notion which is comparable to the objection Dijksterhuis formulated against the mechanistic identification of the universe with a machine, namely that it implies that a programmer, god-like or not, who has programmed nature to realize a particular objective, exists. This is a hypothesis which is difficult to reconcile with the physical character of the informationistic worldview which, just as the mechanistic, is based on the postulate of analysability, that is to say on the hypothesis that reality can be analysed as a collection of elements which are separate from each other and which can be determined logically and independently of each other. This criticism, however, ignores the fact that within the informationistic worldview there is the question of an additional postulate which I will call the *postulate of synthetisability*. According to this postulate, the *form* that a particular configuration of matter and energy has, is repeatedly *matter* for a more complex form of organization at a higher level. In such a process the informational sum is greater than the parts. The evolution of life on earth is a good example of such a process of self-organization of information that leads to still more complex informational structures. Looked at from such a 'bottom-up' perspective, the view that the physical universe is an information-processing machine does not necessarily imply the existence of a divine programmer. The idea that information-processing systems are capable of self-organization also has important implications for the design of information-processing machines (cf. Paul and Cox 1996: 117f.; Winograd and Flores 1987). Research in the field of neural networks and genetic algorithms – that is to say algorithms which develop according to the principle of unnatural selection – suggest that the design of increasingly more complex computers in the future will be carried out by computers themselves on a far greater scale than is presently the case.

The second meaning that can be ascribed to the expression 'informatization of the worldview', after an analogy with Dijksterhuis, is that this expression refers to the tendency of the information sciences to look for hidden algorithms behind that which can be experienced through the senses. The premise here is that the actual course of events that take place in reality can be imitated by a computer program. Following Coolen, we could call this premise the *postulate of programmability*.[19] The postulate of programmability gives scientific explanation a new meaning. Within the informationistic worldview, explanation no longer means the linking of atomic elements with the aid of laws, but being able to write a computer program that results in a simulation of the object to be explained.[20] According to supporters of the strong version of the informationistic worldview, being able to construct a simulation adequately explains the phenomenon. If we were able to write a program that convincingly simulates the intelligent behaviour of a human being, then we would actually have constructed an intelligent entity. The famous Turing test is based on this behaviouristic point of departure: when we cannot distinguish the behaviour of the computer from the intelligent behaviour of a human being, then this program can also be termed intelligent.

This brings us to the third meaning which can be ascribed to the informationistic worldview. This says, as it does in the case of the mechanistic world picture, that reality should be described in a mathematical language because this itself is ultimately written in a mathematical language. In this respect the informationistic worldview is clearly a continuation of the mechanistic. But it is also a transformation of it. This mathematical language is no longer primarily the language of mechanics, which describes the movement of bodies, but the language of computer science, which describes the transfer of information.

The fact remains, of course, that the mathematical description is greatly abstracted from the concrete processes of communication that take place in nature. In the foregoing, I observed that the mathematical language of information theory in fact explains only one dimension of the phenomenon 'information' – the syntactic. Up until now, attempts to formulate the semantic and pragmatic dimensions have all failed. This still does not prove, of course, that it would be impossible in principle. But even if these dimensions are formulated, the question remains as to whether all phenomena can be expressed in algorithms. Even in the closed world of mathematics this is not the case. Turing convincingly demonstrated that there are 'countless' numbers which in principle are noncomputable. All this would appear to set fundamental limits to the programmability, and therefore the explicability, of reality (cf. Davies 1992; Gandy 1980; Pour-El and Richards 1982).

The fact remains that the informatization of the worldview has far-reaching consequences for our experience of, and our association with reality. Not only does scientific explanation attain an essentially different meaning through the postulate of programmability, but so, too, do the prediction and control of events. While within the mechanistic world picture the factual laws of nature were the basis of prediction and control, within the informationistic worldview these laws *themselves* are the objects of control. Informationistic sciences such as genetic engineering are no longer limited to the control of matter (the long history of which goes back to the manufacture of the first prehistoric chisel or axehead) and energy (which at the latest began with the control of fire), but are directed at the control of the information contained in the natural laws (Kelly 1994: 126). Moreover, disciplines such as artificial physics and artificial life even manipulate these laws. Here we can speak of a *postulate of manipulability*. When the laws of nature become the subject of manipulation, the way is open to programming new universes. Informationistic sciences can therefore be regarded as *modal* sciences, which are not so much led by the question of what reality *is*, as by how it *could be* (Emmeche 1991: 161). Modal sciences – and here is an interesting parallel with modern art – are no longer primarily aimed at imitating nature, but rather at the creation of new nature. This also has consequences for prediction. Alan Kay once expressed this strikingly in the words: 'The best way to predict the future is to invent it.'

All this does not mean that the informatization of the worldview will lead to total predictability and control, as some hope and others fear. Every form of manipulation and control brings its own form of coincidence and happenstance with it. Just as mechanistic control contends with the problem that complex causal connections and unintentional side-effects place strict limits on predictability and controllability, so too the complexity of informational relationships and unintentional interferences between computer programs will continually and endlessly frustrate the longing to take our fate into our own hands. It is not unthinkable that the measure of unpredictability and uncontrollability in the case of the postulate of manipulability appear to be still greater than in the case of the postulate of controllability. The tiniest deviations in an algorithm often result in enormous deviations from the original result. But this will not restrain humans from endeavouring to manipulate the laws that control our world.

It is obvious that until now the manipulation of natural laws has remained limited to computer simulations of reality. Reprogramming the laws that regulate the physical universe lies far beyond human capabilities and perhaps will always remain so. But in my view there is no doubt whatsoever that an increasingly large part of human life will take place in programmed worlds, of which the now existing VR (virtual reality) systems and the virtual worlds on the Internet (multi-user domains like Alpha-World) are the first, still primitive, forerunners. For their inhabitants, these virtual environments possess a reality that transcends the traditional opposition between reality and illusion. Although when measured against physical reality they are make-believe worlds, they bring about real effects in the lives of those who enter into them. This appears to justify the prediction that the domestication of information, in a much more radical manner than the domestication of matter and energy within the mechanistic world picture, will lead us into a new world, or, to be more precise, into a multitude of new worlds. And just as those who took the first steps in the mechanical world could barely comprehend the far-reaching implications of those steps, so, at present, it is not given to us to catch much more than a glimpse of the fundamental changes that still await us.

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NOTES

1 Although the first fully electronic calculating machine, the Electronic Numerical Integrator And Calculator (ENIAC), was built little more than fifty years ago in 1946, the history of the computer actually began at least 5,000 years ago with the invention of the abacus. The abacus can be regarded as an *analogue* computer: it is a device that works out mathematical problems on the basis of a physical analogue for which the same mathematical equations apply as for numbers. The beads on the abacus represent ones, tens, hundreds and so on, and mathematical calculations are carried out by sliding them back and forth. The slide rule, which came much later, is an example of a similar analogue computer.

The first mechanical calculator was probably built by the German scientist Wilhelm Schickhard. His ‘calculating clock’, described in detail in a letter to Keppler in 1623, could carry out the four elementary arithmetical operations. Conversely, the pascaline, constructed by the philosopher and mathematician Blaise Pascal in 1642, could only add and subtract. In 1694 his German colleague Gottfried Wilhelm von Leibniz constructed a calculator which, apart from adding and subtracting, could also multiply, divide and calculate square roots. Although this machine still worked according to the analogue principle, Leibniz also invented the binary system which is employed in modern-day digital computers. Despite the remarkable achievements of Pascal’s and Leibniz’s mechanical calculators, their invention went practically unnoticed in the century which followed. It was only in the nineteenth century, in some measure due to the Industrial Revolution, that further development of the computer was addressed. In 1801 the French weaver and inventor Joseph Jacquard designed a loom which was fully programmed with the aid of punched cards. A few decades later the British mathematician Charles Babbage and Augusta Ada Byron designed the prototype of the modern computer. Their Analytical Machine, which was not built by the inventors themselves because they lacked the necessary technical skills, had an input mechanism which worked with punched cards, a 'memory' for storing data, a device to perform mathematical calculations and a printer to record the results.

At the end of the nineteenth century the American Herman Hollerith designed the first electric calculator. It was a great success and Hollerith founded a company to produce it, a company which would later become International Business Machines (IBM). On the eve of World War II, in Germany as well as in Britain and the United States, a good deal of money and energy was devoted to the further development of the mechanical calculator for the purposes of ballistics and cryptology. Alan Turing's article 'On Computable Numbers' (1937) was of great theoretical importance. In this article he demonstrated that in principle every computable number can also be calculated by a machine. Turing also introduced the idea of a universal machine, that is to say a machine which in principle can simulate every classical machine. In 1941, in Germany, Konrad Zuse built the first computer that could be programmed with the aid of the binary system developed by Leibniz. This machine used perforated film for the input and output of the ones and noughts. The first completely electronic computer, the above-mentioned ENIAC (which was commissioned by the American Ministry of Defense and built in 1946 by John Mauchly and J. Presper Eckert), contained 19,000 radio-valves. Although this machine was relatively fast – it could perform 5,000 additions and 300 multiplications per second – its preparation was exceptionally labour-intensive: the components had to be connected by hand in a different way for each new task. Based on a design by the Hungarian-American John von Neumann, building on the ideas of Babbage and Byron, the first computer that was no longer programmed by rewiring the components but by feeding a series of instructions into the memory, was built in Cambridge in 1949. This Electronic Delay Storage Automatic Calculator (EDSAC) marked the birth of the first generation of digital computers. The development of the second, third and fourth generation of computers, in which the radio-valves were replaced respectively by transistors (1957–64), integrated circuits (1964–77) and 'large scale' integrated circuits that made it possible to mount a complete computer on a single chip (1975–), has meant the speed of computers increased exponentially (the Pentium chip which Intel brought onto the market in 1993 has 3.1 million transistors which together can carry out 100 million instructions per second), but the general architecture of the computer has undergone hardly any fundamental changes since the first generation.

2 The fact that information technology plays a crucial role in the present transformation of our culture does not imply that technology unilaterally determines societal change or functions as an independent agency in history. Technology is part of complex pattern of interaction in which it is both a cause and an effect. Technological determinism and social constructivism each offer a partial truth. However, as T.P. Hughes has argued, technologies, as they grow larger and more complex, build up a certain *momentum*, and then tend to be more shaping of society and less shaped by it (Hughes 1994). In this article I will exclusively focus on the way present information technology shapes our worldview, ignoring the complex and contingent processes that led to the current state of this technology. Likewise, I will abstain from discussing the many differences between the various branches of information technologies and, instead, will focus on some of the basic characteristics that almost all of these technologies appear to have in common, despite these differences.

3 One well-known example is the computer-generated proof furnished by Haken and Appel of the proposition, dating from the last century, that a maximum of four different colours are necessary for the preparation of any arbitrary geographical map. For a discussion of the implications of the computer for the mathematical method, see Hersh 1997: 52–7.

4 It is, for example, remarkable (although not exceptional) that in Stillings' earlier-quoted introduction to *Cognitive Science*, in which it is argued that cognitive science assumes that the mind is an information-processing system, the concept 'information' does not appear in the index!

5 This interpretation of ontology deviates from the traditional interpretation under which the concept applies to statements on the most fundamental grounds and causes of reality itself. In accordance with the transcendental and hermeneutic tradition, I use 'ontology' as a phrase that no longer primarily refers to beings, but to the *being* of these beings as it is conceived by human beings (cf. Heidegger 1979: 2–15).

6 The concept 'worldview' (*Weltbild*) is used here in the sense it was given by Wilhelm Dilthey in his theory of *Weltanschauung* . For a detailed discussion of this theory, see De Mul 1999b. The word *wereldbeeld* in the original Dutch title of Dijksterhuis' study (*De mechanizering van het wereldbeeld*) is the Dutch equivalent of the German *Weltbild*. For that reason, a better translation of the title would have been *The Mechanization of the Worldview*. In the text the phrases 'worldview' and 'world picture' (as used by Dijksterhuis' translator) should be read as synonyms.

7 Actually this was precisely the way Turing developed his idea of a universal machine, by giving a formal description of the procedures followed by human mathematicians when they solve a mathematical problem (Turing 1937). However, many followers of Turing reversed this order and started to describe all mental processes as a series of algorithms.

8 This happens, as I have argued in the foregoing, in cognitive science for example. Such an interpretation is legitimate in so far as it offers a fruitful framework for interpretation of the human mind. However, like the mechanistic interpretations of man that, in the seventeenth and eighteenth centuries, interpreted man from the perspective of the machine technologies of those days, such as the clock (a paradigmatic example is Lamettrie's *L'Homme machine* from 1748 (Vartanian 1960)), traditional cognitive science often forgets the metaphorical character of this framework. In fact it forgets *two* metaphorical transfers. First, the concept of information is transferred from the human context to that of the machine. As a result of this transfer, the concept acquires a different meaning. Subsequently, this concept is transferred back from the domain of the 'information-processing machine' to the human context. The computer now becomes a metaphor of the human mind. However, when the two metaphorical transfers are forgotten, the human mind is literary regarded as *being* a machine that processes information like a computer (cf. Coolen 1997: 34). In the section 'The Concept "Information" ' we will see why this is a misleading and inadequate claim.

9 This definition follows in a slightly adapted form the definition G. Ropohl has developed on the basis of the semiotics of Morris and Peirce (Ropohl 1986: 65–7).

10 See, for example, Dawkins 1995: 27–35. In this pragmatic dimension we are already given the opportunity to empathize with a machine in a particular way. The *Tamagotchi* is an interesting example of this. Although children in general realize the little digital creature which they are attempting to bring up is not a living creature, the fact that the creature

can 'die' through lack of attention can arouse quite intense emotions. Digital graveyards too appeared on the World Wide Web. Sherry Turkle offers a interesting analysis of the deliberate attribution of intentions to machines with the development of the computer (Turkle 1984, 1995).

11 The example just given can elucidate this: although the French word *mouton* has 'sheep' as its counterpart in English, the content of meaning is not the same, because in English, in contrast to French, there is a separate word for 'sheep-meat' – namely 'mutton'.

12 The distinction made here is simplified and broad-based in nature: in reality we are concerned with a broad continuum between the lifeless and the most complex organisms.

13 According to Kramer-Friedrich, the reason the myths (mentioned earlier) have formed around information-processing machines lies precisely in the misunderstanding of the distinction between electronic signals and the information they carry (Kramer-Friedrich 1986: 20).

14 True as this may be, the semantic and pragmatic dimensions remain relevant to the development of a concept of information that extends further than the answer to the question of what is the most efficient way to transfer electronic signals.

15 Wiener's interpretation is linked to the way in which information is generally defined in biology. Living creatures appear to violate the second law of thermodynamics: where this law states that physical systems tend to greater disorder, the organism creates order from disorder. In reality, however, no violation takes place here because the greater order achieved in the organism is at the cost of a still greater disorder elsewhere (Schneider and Kay 1995).

16 This suggests that syntactics can indeed be studied separately from semantics and pragmatics, but that this dimension is not without relevance to other dimensions.

17 'Information' is used here with the meaning Wiener ascribes to the concept. On the basis of Shannon's definition of entropy, we could also assert that the playing card contains maximum information in the sense that here the uncertainty is at a maximum.

18 C.F. von Weizsäcker undertakes an interesting, although rather hesitant, attempt to do this in 'Materie, Energie, Information' (Weizsäcker 1974). A more recent, nonreductionist, approach to the relationship between matter, energy and information is offered by D.J. Chalmers in *The Conscious Mind* (1996).

19 Seen in the light of this postulate, in the informationistic sciences the postulate of analysability has two connotations:

> On the one hand every task to be carried out by the machine must be divided into sub-tasks and these again into still smaller sub-tasks. On the other hand, the knowledge of the 'world' with which the actions of the machine are concerned must be presented in the form of a structure of atomic elements.
>
> (Coolen 1992: 46)

20 However, given the possibility of genetic algorithms mentioned above, it is not by definition taken for granted that a human being acts as programmer. Supporters of the more recent evolutionary approach in research into artificial intelligence and artificial life (a-life) state that the complexity of many phenomena exclude a 'top-down' approach. If the human brain could be captured in a computer program then it would require hundreds of millions, if not billions, of lines of code. Certainly when one thinks that the number of

unwanted interactions between the instructions of a program increases rapidly with the magnitude of the program, it is clear that programmability seen from a human perspective is strictly limited.

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