The foundations of information science. Part I. Philosophical aspects

Bertram C. Brookes
64, Abbots Gardens, London N2, 0JH, UK

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This is the first of a four-part paper on the foundations of information science. The second part, on quantitative aspects, will appear in the next issue of the Journal, and the final two parts in subsequent issues.

It is first argued that a niche for information science, unclaimed by any other discipline, can be found by admitting the near-autonomy of Popper's World III – the world of objective knowledge. The task of information science can then be defined as the exploration of this world of objective knowledge which is an extension of, but is distinct from, the world of documentation and librarianship. The Popperian ontology then has to be extended to admit the concept of information and its relation to subjective and objective knowledge. The spaces of Popper's three worlds are then considered. It is argued that cognitive and physical spaces are not identical and that this lack of identity creates problems for the proper quantification of information phenomena.

1. Introduction

1.1. The founding of a science

Any social activity claiming to be a science has to be theoretical as well as practical. It has to begin *in media res* with commonsense rationalizations of easily observable phenomena that attract interest. Gradually, and with persistence, we form structures of theory which, through critical discussion attain a degree of consensus among those who contribute to that discussion. The theoretical structure of a science is never complete or closed; every aspect of it remains always open, offering new problems.

Once the nucleus of a new theory is discernibly coherent there are two ways in which it can develop: first, by growth of the superstructure resting on the initial foundations, so extending the range of the theory; and, secondly, by deepening or strengthening its foundations. These foundations are the set of basic assumptions initially taken to be self-evident. As long as the superstructure continues to grow freely – as long as the initial paradigm remains fruitful – no-one worries unduly about the foundations. It is only when the growth of the superstructure begins to lose its first confident pace that we begin to question the basic assumptions. By this time, however, the basic assumptions have become implicit. We have to dig them up to see exactly what they are.

1.2. The state of theoretical information science

Theoretical information science hardly yet exists. I discern scattered bits of theory, some neat in themselves but which resist integration into coherence. So there are no common assumptions, implicit or explicit, which can be regarded as its theoretical foundations. Information science operates busily on an ocean of commonsense practical applications which increasingly involve the computer. Whatever foundations it may claim to have rest on commonsense views of language, of communication, of knowledge and information and on commonsense applications of computer and telecommunications technology. Computer science is in little better state.

So information science floats in a philosophical limbo. It has no theoretical foundations. That fact at least simplifies my present problems – there is nothing first to dig up! The ground is already clear.

1.3. The antiquity of the basic problems of information science

The basic problems of information science are not new. They reach back through epistemology, or the theory of knowledge, to Plato's theory that abstract entities such as those of mathematics exist outside physical space and time in an autonomous world of timeless essences and also to Aristotle's formalization of logic. The theory of knowledge still occupies a central position in the perennial philosophy though some aspects of it have already become, through

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psychology and neurobiology, important modern sciences.

To justify the claim made explicit in the name the new subject has adopted, the theoretician of information science has to show that in some significant way the new science reaches beyond the current philosophy, beyond the current psychology of mind and neurobiology of the brain to new areas and problems it can legitimately call its own.

1.4. Information: subjectivity and objectivity

The concept of information offers peculiar difficulties to the theoretical scientist. Even at the commonsense level and however it may be thought of, information is an entity which pervades all human activity. It is therefore peculiarly difficult to observe information phenomena in isolation with the kind of detachment that scientific enquiry traditionally demands. Even the process of describing one's observations of some phenomenon is itself an information activity. So the separation of objective from subjective effects is not easy to maintain. Is it even possible?

This question is crucial. In the natural sciences we can assume with some confidence that our observations to not themselves disturb the phenomena we are observing, except, of course, at the level of quantum physics. But in the social sciences we can not assume that human behaviour is unaffected by observation or by the observer's unconscious responses to the behaviour of those he observes. The boundary between objective and subjective description becomes very fuzzy indeed.

All the social sciences face this difficulty but none of them has faced up to it. And, of all the social sciences, information science is most intimately concerned with the interactions between mental and physical processes or between subjective and objective modes of thought. A special responsibility therefore rests on information science to clarify these issues if it can.

1.5. The practicality of current information science

Information science is now regarded both by the public and by most of its proponents as an essentially practical activity concerned to exploit the computer, the micro-chip and telecommunications technology. There is no end in sight of the possible extensions of mechanized information systems which, though dependent on the sciences underlying the modern technologies, appear to be able to get along with very little information science theory at all. Practical information systems will continue to expand indefinitely without theory until it is sensed by users, if not by the operators of these systems, that present systems are not, from an information point of view, as effective as they are claimed to be. Applicable technology is now superabundant but good applications are all too rare.

So I was cheered when I heard Resnikoff of the National Science Foundation of the U.S.A., at a conference of A.S.I.S. in Minneapolis in November, 1979, give notice that the N.S.F. would begin to take a harsher view of the funding requests made to it. He too had noted the overwhelming interest in practicalities and emphasized the need for more theoretical research aimed at developing what he called 'more appropriate analytical intruments'.

2. The starting point: Popper's three worlds

In trying to find the grounds of information science I have been driven down, level by level, to the rock-bottom of human thought – to metaphysics. In discussing metaphysics, the best one can do is to assert one's own assumptions as clearly as possible. In metaphysics nothing can be *proved* – only asserted. So the implicit challenge to one's readers at this level is to say in effect 'If you don't like what I say, then offer something better'.

Of modern philosophers I find Sir Karl Popper much the most congenial, precisely for the reasons that most professional philosophers of our time disapprove of his ideas. His first work in our field was *The logic of scientific discovery* (1934) in which he argued that science was concerned not with Truth (in its absolute sense) but with trying to extend our knowledge of the external world by *falsifying* current theories rather than by *verifying* them. Unfortunately, though Popper has been greatly concerned with the growth of scientific knowledge, he has taken no cognisance of the concept of *information* on which we so heavily depend. So though I begin with Popperian ideas, I have to extend them in my own way to complete the metaphysical groundwork I believe we need.

The most immediately relevant of Popper's books is his *Objective Knowledge* (1972). In his preface, Popper writes: "The phenomenon of human know-

ledge is no doubt the greatest miracle in our universe. It constitutes a problem that will not soon be solved .... Since Descartes ... the theory of human knowledge has been largely *subjectivist:* knowledge has been regarded as a specially secure kind of human belief, and scientific knowledge as a specially secure kind of human knowledge. The essays in this book break with a tradition that can be traced back to Aristotle – the tradition of the commonsense theory of knowledge ... I regard the *commonsense theory of knowledge* as a subjectivist blunder. This blunder has dominated Western philosophy. I have made an attempt to eradicate it and to replace it by an objective theory of essentially conjectural knowledge."

My own intuitions resonate with Popper's words. What information science needs at its roots, it seems to me, is an *objective* rather than a *subjective* theory of knowledge. Any line of thought which claims to be scientific should be dealing with *objectivities* rather than with *subjectivities,* though these are terms I need to clarify.

Popper's words remind me that my colleagues in librarianship also use the term *knowledge* in an objective way. They speak and write about 'the organization of knowledge', though when I looked into their works I found that they discussed only ways of classifying *documents.* But documents and knowledge are not identical entities.

Up to modern times philosophers have recognized the reality of either *one* or *two* worlds. For example, Plato was a dualist, though of a special kind. Berkeley was a monist; his only reality was that of the mental world. Another monist was T.H. Huxley, the popularizer of Darwin's evolutionary theory – a materialist – who disparagingly dismissed mental states and conscious thought as 'the steam above the factory'. Nowadays, most philosophers and most other people too, I guess, are dualists: they recognise the physical world and the mental world as independent, autonomous realities.

But Popper goes further. He recognises a third world, that of objective knowledge which is the totality of all human thought embodied in human artefacts, as in documents of course but also in music, the arts, the technologies. These artefacts enshrine what Popper declares to be his autonomous – or near-autonomous – world of objective knowledge.

So here is Popper's ontological scheme:

World 1. The physical world, the cosmos in which Earth, vital though it is to us, is but an insignificant speck in the immensity of the universe of radiation and matter.

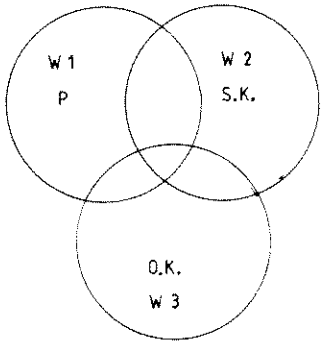

Fig. 1. Popper's three worlds.

World 2. The world of subjective human knowledge or 'mental states'.

World 3. The world of objective knowledge, the products of the human mind as recorded in languages, the arts, the sciences, the technologies – in all the artefacts humans have stored or scattered around the Earth.

Though these three worlds are independent, they also interact. As humans living on Earth, we are part of the physical world, dependent for our continued existence on heat and light from the Sun, oxygen from the air, fresh water from springs, carbohydrates and proteins from our foods, and so on. Through our mentalities we are also part of World 2. In reporting the ideas Popper has recorded in his books, I have been calling on the resources of World 3. Books and all other artefacts are also physical entities, bits of World 1, shaped by humans to be exosomatic stores of knowledge which have an existence as physical things independent of those who created them.

It is the autonomy Popper ascribes to World 3 that traditionalist philosophers question. The subjectivist is prepared to admit that an artefact such as a book is in part a physical object and so a component of World 1. But the subjectivist would then argue that the mental component of a book remains only potential; the knowledge it offers has to await the human reader who picks it up and transduces its lines of print into the thoughts its author there expressed. And this is a World 2 exercise. The subjectivist might further argue that in metaphysics particularly we should employ an Ockham's razor economy principle and recognise no more autonomous worlds than are necessary.

Popper argues that animals other than humans also make artefacts. For example, a bee-hive remains a bee-hive, an objective entity, even if its colony of

bees is wiped out by some disaster. And the empty bee-hive tells us much about the way of life of its one-time inhabitants. It is now possible to imagine a burst of radiation emitted by some nuclear catastrophe which could extinguish all human life on Earth and yet leave our artefacts intact. As all radiation decays, there would come a time when it would be feasible for non-human forms of intelligent life, from some other planet possibly, to arrive on this desolate Earth and find the human artefacts scattered around the scene, including the intact libraries, and, as man has already decoded the Minoan scripts, gradually decode our documents. It would thus be possible for our visitors to recover what man had learned about his worlds. In other words, once human knowledge has been recorded, it attains a degree of permanence, an objectivity, an accessiblity which is denied to the subjective knowledge of individual humans. A gifted human may acquire wide knowledge, deep wisdom and spiritual insights but all this is lost when he dies except for that which he has recorded in some artefact.

Other doubts about the autonomy of World 3 arise, I guess, from human modesty. Worlds 1 and 2 were created by God or by whatever other cosmic forces one acknowledges, whereas World 3 is essentially man-made, though of course one can also similarly argue that the same non-human cosmic force lies behind all human activity. But Popper, I think, is recognising the inestimable value to humans that has followed the development of language and of writing particularly. I do not think it an exaggeration to acknowledge a World 3 of the kind he describes.

3. World 3 and information science

Popper's World 3 should commend itself to library and information scientists because, for the first time, it offers a rationale for their professional activities which can be expressed in other than purely practical terms. Natural scientists and technologists explore and exploit World 1 and deposit their records and artefacts in World 3. Social scientists and humanists study and reflect upon World 2 and the interactions of World 2 with World 1; they too deposit their records and artefacts in World 3. Pure mathematicians invent abstractions and work out their interrelations, a study within World 3 itself, and they too deposit their records in World 3. So the *practical* work of library and information scientists can now be said to collect and organise for use the records of World 3. And the *theoretical* task is to study the interactions between Worlds 2 and 3, to describe and explain them if they can and so to help in organizing *knowledge* rather than *documents* for more effective use.

The artefacts which record human knowledge exosomatically become independent of the knowing subjects who created them. These artefacts are no longer subjective and inaccessible but objective and accessible to all who care to study them, as are the flints and sherds that archaeologists study except that we are dealing with modern artefacts. So Popper talks of 'epistemology without a knowing subject', i.e. the *objective* study of knowledge. It is this idea that gives us also the justification for establishing a new science.

This approach thus enables us to escape from the subjectivities of the 2000-year old approach to theories of knowledge and from subjective psychology as well as from traditional philosophy. Furthermore, in adopting the interaction between Worlds 2 and 3 as our field of study we are laying claim to a territory which no other discipline has already claimed.

When visiting schools of information science in North America I have often been introduced to the faculty members in the following terms: "Here is Dr. A, he teaches *linguistics* for information science. And here is Prof. B who gives courses in *computer science* for the information scientists. Dr. C here is a statistician who has a course on *statistics* for information science." And so it goes on until I am compelled to ask: "And who teaches *information science?*" The usual answer is that information science is a peculiar mix of linguistics, communication, computer science, statistics, research methods, together with some techniques from library science such as indexing and classification. Any integration of these elements has to be achieved, if that is possible at all, by the students themselves.

But I am arguing that information science is a discipline which has its own unique territory, its own unique problems and its own unique view of human affairs which now has to develop its own principles and techniques. It has no future as an incoherent mix of elements from an arbitrary set of disparate disciplines.

4. Information and sense-data

At this point I have to leave Popper and go forward on my own. I am interested in *information*

as well as *knowledge* but Popper sadly ignores the concept of information. It may be that he wrongly identifies *information* with *sense-data,* a philosophical concept which Popper has done much to discredit. The term *sense-data* he knows only in relation to naive empiricist views derived from Locke, Berkeley and Hume which he has criticised strongly. His main criticism stems from the obsession of these philosophers with the search for Truth while Popper has always emphasised that Truth is something we can never knowingly attain and that all our knowledge, however acquired, is always provisional, always open to criticism and correction.

In his later works, notably in *The self and its brain* (1977) written jointly with Sir John Eccles the neurobiologist, he has reverted to a more traditional philosophical problem – the relationship of the mind to the body – which, interesting as it is, is not directly relevant to the issues I am concerned with here.

Moreover, I have to be critical of some aspects of Popper's three-world ontology in taking the next steps forward.

5. The problem of spaces

Popper leaves his three-world model incomplete. He does not, for example, explain what he means by a 'world'. The physical world, World 1, is occupied by matter and radiation. World 2, the world of subjective mental states, is occupied by our thoughts and mental images, and World 3 by objective knowledge. In short, Popper describes only the objects or entities he assigns to these worlds. But different 'worlds', I take it, have not only different kinds of furniture but may also have different kinds of *space.*

If we do not consider the possibility that different worlds may have different kinds of space, we tend to assume that all the spaces are identical with the one space we have explored in some detail – that of physical space. Popper himself does not consider this question. In *The self and the brain*, Eccles raises the question: "Where is the self-conscious mind located?" (p. 376) i.e. in relation to the brain. Though Eccles admits that this question is 'unanswerable in principle', he does not explicitly state that he places the mind in World 2 and possibly therefore in a different kind of space. Nor does Popper come to the rescue.

Eccles then adds: "If as conjectured the self-conscious mind is not a special part of World 1, it is likely to have different (i.e. non-physical) fundamental properties . . . it need not have the property of spatial extension." Thus the only space that Eccles has considered is that of the physical space occupied by the brain.

I would now add: "If as conjectured mental states and physical entities belong to different worlds, these worlds are likely to have different spaces". I realise here that I am now extending the usual meaning of *space* from its everyday sense and also beyond that of the mathematician who can deal with 3- or 4- or *n*-dimensional spaces in World 3. So we have to consider in what characteristics mental space may differ from those of physical space.

Here are my conjectures about mental spaces. Each of us bodily occupies a different location in physical space. So each of us has a different mental image of our physical surroundings. But if we were all sitting in a theatre, there would be a simple relationship between our mental images of the stage and our location within the theatre. If we replaced our eyes by suitable cameras and photographed what each of us sees, each from our different points of view, it would be possible, I guess, to look at the anonymous photographs and correctly locate the position each of us accupied in the theatre. So in this case there is a simple relationship between our mental images and the physical realities we observe.

If, however, I ask you to shut your eyes to exclude all visual sense-data and ask you to recall, say, having breakfast today, there is no longer much common ground we share. Most of us will have very different mental pictures. And each mental picture is inaccessible to anyone else.

So what I am suggesting is that there is not one mental space for World 2 but very many. Each of us has his own. Each mental space is unique. Is then a *science* of World 2 feasible? Science looks for uniformities rather than for uniquenesses.

We have different physical bodies as well as different minds. These differences in our physical constitution have not deterred biologists and medical scientists from developing their sciences and carrying on their useful trade. What they soon discovered of course was that we all have identical sets of physical components such as hearts, lungs, brains, limbs, and so on. It is therefore possible for them to generalise about the physiology of the various organs and mechanisms we depend on and to note individual deviations from the norms. Though each of us has a

different mental space, it may be possible to show that all human mental spaces have some common characteristics just as human bodies do.

If such common characteristics do exist, we are more likely to find them when we focus our attention on some common item of interest than when we allow free play to our imaginations. These items of common interest might well be World 3 artefacts. If we want to pursue this line of enquiry, all we need to do is to study the interactions between Worlds 2 and 3 *as reported in World 3.* The documents in our libraries offer us all the evidence – the publicly observable *objective* evidence – we need. All we have to do is to observe how recorded knowledge grows and changes year by year in specific fields, preferably, to keep things initially as simple as possible, in one of the sciences.

Such a study would be analogous to our exploration of the physical world. That began with the exploration of our immediate environments in the ancient civilisations. It was extended by the navigators of the seas and the explorers of the unknown continents. More recently man has begun to explore the physical space around the Earth. World 3 presents a whole new world for us to explore.

The exploration of the physical world, however, depended on the invention and use of objective measures of length, volume and so on. We gradually objectivized our surroundings by measuring them in non-subjective ways. It seems to me therefore that we need to consider how to measure whatever we decide it is necessary to measure in the spaces of Worlds 2 and 3. I am seriously questioning whether the analytical and quantitative modes of thought we devised for the exploration of the physical world are appropriate for the exploration of Worlds 2 and 3. So far, it seems to me, we have unthinkingly assumed that the analytical techniques which have been so successfully applied to the physical phenomena of World 1 are also appropriate to the explorations of the mental spaces of Worlds 2 and 3. If, as Resnikoff has suggested, we need better analytical instruments in information science, it may be that we have to consider discarding at least some of the techniques we have tried to use and to begin again *ab.initio.*

6. The accessibility of objective knowledge

My brief analysis of the problems of spaces now enables me to relate the terms *subjective* and *objective* to the spaces I have mentioned. Objective events can occur only in those worlds which have *one* space, namely, Worlds 1 and 3. The events of World 2 – of our individual mentalities – occur in our individual *private* spaces and are thereby *subjective*. In order to objectivise our individual thoughts we have to express them and deposit the records in World 3 where they are accessible to, and can therefore be critically considered by, others.

But this explication of *objective* and *subjective* points to a further problem which Popper has not considered. It is not good enough to imply that any expression of thought (or of feeling) deposited in World 3 is immediately accessible as an *objectivity* to anyone seeking it. If I want to know what X wrote in some document I can adquately specify, there is of course no problem. I could reasonably hope to find a copy of the document and read X's words there. But if I go to the British Musuem Library to discover, say, the causes of the first World War, I know that I should find a very large number of relevant documents. The objective view of this complex issue is not immediately discernible. When I begin to read the documents, I am liable to find many conflicting or even contradictory statements. I then have to apply my judgement to decide which of the accounts I have read appear to me to be the most plausible or authoritative. So I am left with my own subjective view – a view widened and balanced (one would hope) by the reading of the documents. But the point is that World 3, in spite of all the efforts of librarians to classify the *documents* they have collected, is not the tidy world of immediately accessible knowledge that Popper appears to present.

I am little better served, of course, if I go to the mechanized scientific data-bases and put a query there, say, to discover present knowledge about the origins of the solar system. Again I would expect to get a large file of references. When I had located and read the documents, again I would find similar conflicts and contradictions, though in science one would expect to find a closer consensus than in political history.

Much work therefore remains to be done to organize World 3 so that the objective knowledge it offers i.e. the current consensus, is more immediately accessible. Only the first steps – the classification of the artefacts – has so far been attempted. Can we go further? I believe we can. We should at least be aiming to go further. I return to this matter in more detail in Part III.

7. Information and knowledge: the 'fundamental equation'

What is the relation between *information* and *knowledge?* I regard *knowledge* as a structure of concepts linked by their relations and *information* as a small part of such a structure. The knowledge structure can be subjective or objective.

Some years ago I expressed this relationship by what I called the 'fundamental equation':

$$K[S] + \Delta I = K[S + \Delta S], \qquad (1)$$

which states in its very general way that the knowledge structure $K[S]$ is changed to the new modified structure $K[S + \Delta S]$ by the information ΔI, the ΔS indicating the effect of the modification.

I have expressed the equation in pseudo-mathematical form because it is the most compact way in which the idea can be expressed. But the mathematician will note that my terms and symbols are undefined. The equation says little more than I have already explained but it serves to emphasize how little we know about the ways in which our knowledge grows.

There is, however, one point which is implicit in such an equation but which must be stated clearly. The equation implies that if its entities were measurable, they would have to be measured in the same units, i.e. that information and knowledge are of the same kind. As defined here, *information* is a small bit of *knowledge* and so it would be correct to substitute ΔK for ΔI in eq. (1). But it is useful to adopt my original notation in general because the same ΔI may have different effects on different knowledge structures.

The fundamental equation also emphasizes that *information* so defined is not identical with the philosophers' *sense-data.* Information may, of course, depend on sensory observation, but the sense-data so received have to be subjectively interpreted by a knowledge structure to become information.

The equation is also intended to imply that the growth of knowledge is not simply accretive. The absorption of information into a knowledge structure may cause not simply an addition but some adjustment to the structure such as a change in the relations linking two or more concepts already admitted. In the sciences, information increments have sometimes led to catastrophic restructuring.

I have conjectured that the fundamental equation applies to both subjective and objective knowledge structures. Popper believes, and I agree, that we shall learn more about *subjective* learning by studying eq. (1) in *objective* rather than in the traditional *subjective* contexts. And I suggest that such a study is a major aim of information science.

What is being asserted is that the publicly observable growth of knowledge as recorded in the published literature reflects the ways in which individual minds think privately. In any case, there is no way of inspecting the private knowledge structures of an individual without eliciting his response to questions as, for example, by written examinations. In subjective studies we thus have to use 'black box' techniques to find the private knowledge structure, shaping whatever we elicit by comparing the output with our own subjective structures. This seems to be a methodologically precarious technique to adopt when the same problem can be studied objectively.

I shall describe and comment on recent work in this direction in Part IV.

8. Information: verbal and non-verbal

For me as a scientist, information is not only linguistic. The scientist's primary source of information is the natural world though he scans it with senses tuned by his private knowledge structure seeking some specific kind of information. However, until he reports his observations in some appropriate way, by publishing his paper, his private thoughts are not yet science. Nevertheless, I have to emphasise that information acquired through language is only part of the totality of information potentially accessible to us.

In everyday life we depend greatly on information absorbed from our environment. In moving around the scene we may not be conscious of all the information we are responding to. For example, our sensory mechanisms enable us to walk down a busy street avoiding others who cross our path and yet attend with full concentration to the conversation of a companion. We consciously attend only to those events which are most important to us at the moment and yet respond to other sensory inputs which bear on our situation.

Studies of subliminal perception show that in experimentally contrived situations we do in fact respond as though the subliminal percept had been consciously received. I have no doubt that here is a very useful sensory mechanism which bears on many

aspects of daily life. The existence of this mechanism also throws doubt on the rationalist belief that one can be cognitively aware of all the sources of information that bear on any particular problem. In subjective studies we can never be sure that we have all the relevant data.

The sensory systems we have evolved are very well adapted to life on Earth. But they are selective. They do not respond to many forms of radiation that envelop us. For example, the visible light to which our eyes respond constitutes only one of the 60 or so octaves of the spectrum of natural electromagnetic radiation. So though the night sky has an abundance of visible stars, for example, it is now known that there are many other stars invisible to us because they emit only X-rays. The panoply of the night sky is much richer than appears to our eyes.

For theoretical purposes I have invented a "gedanken-instrument", a purely imaginary device not unlike the space-probes the Americans have recently sent to Jupiter and Saturn to get a closer look at those planets. It is a private versatile miniature space-probe or universal 'bugging device' which can be tuned to pick up any kind of radiation. It then transduces and transmits back to me, in forms my senses respond to, the signals it receives. I can place it where I wish. I call it a *perceptron.*

I use the perceptron at present only to emphasise that potential information is everywhere. The space above my desk looks empty. But if I were to send my perceptron up there tuned to visible light, it would observe me at my typewriter. Tuned to the wavelength of BBC 3 it might respond with Mozart. And so on.

The seemingly empty space around us is seething with potential information. Much of it we cannot be aware of because our senses do not respond to it. Much of it we ignore because we have more interesting things to attend to. But we cannot ignore it if we are seeking a general theory of information. We cannot live only by reading and writing books.

Some highly rational people appear to think that the world of human knowledge is closely bounded by a linguistic envelope, so that what cannot be said cannot be known – "thereof we must be silent". I acknowledge that words are very, very important. It is the prime duty of every scholar to try to express in words ideas that have not been expressed before. I emphasize, however, that we have a long, long way to go. Some highly rational people also demand hard definitions of all technical terms and a rigorous logic relating them. But in trying to develop a scientific theory we need to allow both our words and our logic to retain some flexibility. There must be some 'play in the gears' to allow space for imagination and adjustment in the light of new evidence. The words and the logic will harden as the knowledge structure grows.

Apart from these considerations, Popper also ascribes to Worlds 2 and 3 all the non-linguistic arts such as music, painting, sculpture, architecture and all other non-verbal products of the human mind, technological as well as artistic. They all tell us something about ourselves. We should not draw exclusive boundaries before we have to.

9. The furniture of the mental worlds

Earlier in this paper I complained that Popper had merely furnished his three worlds without considering the nature of the spaces these furnitures occupied. Let us have a closer look at the furnitures themselves.

World 1 is furnished with matter, energy and radiation. Everything physical can be assigned to World 1.

Worlds 2 and 3 are furnished with information and knowledge – and with feelings too. Everything mental can be assigned to Worlds 2 and 3. So what does the furniture of Worlds 2 and 3 comprise? As far as I can see, only information and knowledge. Nothing more.

No physical entities whatever have any place in the mental worlds. So theories of information cannot entertain physical entities or even ambiguously named entities such as books or documents. A book is both a physical thing and a potential source of knowledge. So in using the term *book* we have to make our reference clear in this context: are we referring to the physical or the mental aspect of the book?

I therefore emphasize the distinction we have to make and maintain in developing a theory of information: the fundamental entities of World 1 are matter, energy and radiation; the fundamental entities of Worlds 2 and 3, as fundamental to these worlds as matter and energy are to World 1, are information and knowledge.

This distinction implies that an analysis which uses as its primary data physical entities can produce a result which is interpretable only in terms of physical entities. To analyse information and knowledge we have to operate on purely mental entities.

This distinction and its implications will be more fully discussed in Part II.

10. Subjective and objective information

If there is objective knowledge, then by eq. (1) there should also be corresponding objective information.

The idea of the perceptron planted in space and transmitting to me the information it is tuned to collect points to the possibility of objective information. Whatever it picks up is objective information, i.e. information which could be shared by anyone who tapped its transmission link with me. But when that objective information reaches us it becomes subjective to each of us.

When we listen to the radio news we may similarly get objective information because it is shared by everyone else who is listening. What we hear objectively may be the subjective views of some political commentator who will doubtless evoke our own subjective response to his comments.

In this age of micro-chips, objective information abounds. There is, for example, a device for spraying car bodies with paint. A car body is placed in position and an expert human sprayer seizes the spray-gun connected to a micro-chip set to 'learn'. The expert sprays the car body taking care to cover all the awkward corners and crevices. That body is moved away and the next unpainted car-body takes its place. The machine is automatically switched on to operate. The spray-gun repeats exactly the motions it has 'learned' and, when the spraying is complete, switches off the supply of paint and awaits the positioning of the next car body.

The information that the human sprayer had previously had to convey by words and actions to human recruits is now replaced by the signals transmitted to the machine by the expert's movements and stored there in its memory. The machine is not 'intelligent' of course. If the next car body happens to be incomplete, the machine, once triggered into action, will spray as if the body were complete. The machine does exactly what it has been programmed to perform. The information it uses is simply a timed sequence of signals; it has not been structured into knowledge. It remains objective information.

Measures of information – of *objective* information – were proposed 50 years ago and are used in Shannon theory applied to telecommunications systems and computers, for example. As far as I know, such measures have not yet been applied to objective *knowledge*, but I see no reason why they should not be, and every reason why they should. Possibilities will be discussed in Part IV.

11. Concluding comments

Human dignity has suffered greatly from modern science. Copernicus struck the first blow by demoting the Earth from the centre of the solar system so that man was displaced from the cosmic-centred authority he had, innocently assumed. Darwin struck a further blow by producing overwhelming evidence that man had not been specially created in the image of God but was descended from apes, and apes, in their turn, from a long line of less distinguished ancestors. Modern medical sciences have made great advances by ignoring the vitalists and by regarding humans as biochemical mechanisms whose vital organs can be transplanted like spare parts. Modern cosmologists have extended the universe in both space and time so making man appear ever less significant in the total cosmic scene.

Recognition of the autonomy of World 3 – the 'miracle', as Popper calls it, of human knowledge – restores, it seems to me, some of man's lost dignity. There is something special about us after all! Our man-made World 3 is very, very precious – a life-line which may save us from extinction. But we need to understand it better than we do. I hope that information scientists recognise their opportunity and accept their heavy responsibility.