The Structures of the Common-Sense World[(1)]

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Introduction

While contemporary philosophers have devoted vast amounts of attention to the language we use in describing and finding our way about the world of everyday experience, they have, with few exceptions, refused to see this world itself as a fitting object of theoretical concern. In what follows I shall seek to show how the commonsensical world might be treated ontologically as an object of investigation in its own right. At the same time I shall seek to establish how such a treatment might help us better philosophically to understand the structures of both physical reality and cognition.

My remarks are prompted by a number of important investigations which have been carried out by non-philosophers in recent years. Thus for example there is the project of a 'semiophysics' a physics of the salient structures in reality that has recently been advanced by the French thinkers René Thom and Jean Petitot.[(2)] There are the experiments of Gestalt psychologists such as Gaetano Kanizsa and Paolo Bozzi demonstrating the existence of a *sui generis* organization of the perceptual world, for example in respect of the categories of colour, shape, motion and contour.[(3)] There is the work of J. J. Gibson and other ecological psychologists on perceptual salience, and on the substances, surfaces, affordances, etc. of the common-sense world.[(4)] There are the investigations of E. Rosch and her associates on the role of prototypicality in our everyday experience, and of F. C. Keil and others on the ways in which our experience is structured via natural species-genus relations.(5) And finally, and for our present purposes most importantly, there are experiments in the field of artificial intelligence issuing in the construction of models not only of the processes of common-sense reasoning but also of commonsensical reality itself.

Common Sense and Artificial Intelligence

As computer scientists have been forced, by degrees, to acknowledge, it is everyday knowledge that is hardest to convey to a computer. Such knowledge is, however, of tremendous importance. For it seems on the face of it that our commonsensical belief-systems enjoy not merely a remarkable efficiency when it comes to solving the problems raised in our everyday passage through the world, but also a no less remarkable adaptability, a capacity to maintain themselves in functioning order from situation to situation and from generation to generation, even in the face of sometimes catastrophic changes in environmental and other conditions. A good deal of effort has accordingly been invested in the construction of theories not merely of our common-sense beliefs but also of different aspects of that common-sense reality in which we live and move and work. One of the goals of the present paper, now, is that of using ideas on common-sense physics derived from artificial intelligence research as a preamble to a philosophical account of the structures of commonsensical reality with pretensions to the status of a theory.

Consider, for example, the so-called 'qualitative physics' of Kleer and Brown (1984). This seeks to predict and explain the behaviours of mechanisms by providing algorithms for determining the patterns of activity of complex devices from the generic behaviours of their components. The latter prove capable of being reduced to a rather small number of basic types, enjoying different but comparable realizations in highly disparate fields. (Conduits, for example, may be used to convey air, water, electric current, information, investment funds, and so on.) In relation to each type of constituent we may then distinguish, again, a rather small number of stable basic states (for example *on*/*off*, *leftward flow*/*rightward flow*), separated by instantaneous thresholds of transition. We are then faced not, as in standard physics, with unsurveyable quantitative continua, but rather with small finite spaces of alternative states, each one of which is perceptually easily distinguishable from its neighbours. Movements into and out of each of the basic states can moreover be represented by means of the equations of a qualitative differential calculus, within which

$$p > 0, dp/dt > 0, d^2p/dt^2 = 0$$

for example, might represent a situation in which the pressure in a given container is positive and increasing at a constant rate.(6)

Or consider the attempt by Gardin, Meltzer and their students to develop a science of naive physics via the consideration of analogical computer-representations of everyday objects such as strings, rods, levers and pulleys. This is achieved via the construction of two-dimensional graphic arrays whose constituents are designed to exhibit patterns of behaviour which are acceptable as qualitatively correct for entities of the given sorts.(7) Strings, for example, can be crudely modelled as one-dimensional aggregates of molecules satisfying the following four constraints, which turn out to be sufficient to give qualitatively correct behaviours in a range of situations:

1. Continuity: there is a fixed distance parameter (e.g. zero) between each molecule and its neighbours.

2. Flexibility: there is a fixed angle parameter, which is an upper bound to the amount the line joining the centres of two neigbouring molecules may rotate.

3. Impenetrability: there is no intersection between the pixels of a molecule with the pixel elements of environment objects.

4. Sensitivity to external forces: forces like gravity, wind, or viscous drag are stored in the data structure of each molecule.(8)

The given approach proves itself to be of high generality. Thus for example by adjusting the flexibility limit angle from 180 to 0 one is able to simulate the behaviour of a rigid bar, and selecting angles between these limits allows the simulation of rods with varying degrees of flexibility.

The constraints in question were discovered by means of trial-and-error experiments on a computer terminal: in this way the capacity of human subjects to recognize the qualitative rightness of a physical set-up governed by a range of variable parameters is used as a research instrument in establishing laws of naive physics. One is reminded here of experiments carried out much earlier, and without the benefits of computer simulations, by Albert Michotte (1946), experiments designed to demonstrate the ways in which (and the conditions under which) things and events in nature are perceived as standing to each other in relations (above all causal relations) of various sorts. The experiments of Michotte and his associates were of course carried out without the benefits of computer simulation. Thus Michotte did not even glimpse the possibility of building up by these methods a model of the entire world of everyday physical objects in interaction. (It must, however, be hastily admitted that Gardin and his associates are far removed from an outcome of this sort.)

The work of Hobbs *et al. (*1988) investigates the ways in which common-sense knowledge is used in understanding texts about mechanical devices and their failures. The resultant 'common-sense metaphysics' amounts to a theory of those core concepts (granularity, scales, time, space, force, causality, change, etc.) which figure in virtually every region of inquiry. Consider, for example, the family of concepts associated with the notion of force. A material body can be said to be shape-invariant with respect to a given force if, on application of that force, its shape remains the same. The topological invariance of a body can be similarly defined. A body will cease to be shape- and topology-invariant when forces beyond certain threshold intensities (say d_1 and d_2) are applied (and note, again, that we have here in each case an example of a basic state-transition of the sort mentioned above). In these terms one can now define what it is for a material to be 'hard', 'flexible', 'malleable', 'ductile', 'elastic', 'brittle', 'fluid', etc.[(9)] Thus for forces of strength $d < d_1$ the material is *hard*; for forces of strength $d_1 < d < d_2$ it is *flexible*, and so on. Similar methods can be used to investigate the family of concepts associated with the different varieties of causal connection between material bodies. The *attachment* of bodies, for example, can be defined by the fact that when either moves so, too, does the other. Attachment in this sense may be either *direct*, or *mediated* via paths of causal connections, and in terms of these notions one can go on to define further notions such as barrier, opening, penetration, and so on.[(10)]

The naive physics of Patrick Hayes countenances a still more general theory incorporating massively large-scale formalizations of common-sense knowledge of a sort that is designed to yield a formal (first-order, axiomatic) theory of the entire domain of commonsensical reality. The axioms of this theory should be intuitively acceptable (this being decided here also in part by introspective means). Naive physics should in this sense be 'intelligent'. But it should also be 'naive' in the sense that it takes as one of its starting points the relevant commonsensical beliefs of normal human beings.

How, Hayes asks, could one construct a robot capable of finding its way efficiently around, say, a salad bar? Such a robot would need to have the capacity not merely to negotiate walls, doors, chairs, tables, and people. It would need also to be able to lift and manipulate crockery and cutlery, tomatoes, lettuce, and other bits, pieces and mixtures, to the extent that in order to succeed in its efforts it would need to be in possession of something approximating to a theory of the entire world of solids and liquids.(11) A physics of the usual sort is of no help to him here. This is first of all because the relevant computations, if they are capable of being carried out at all on a standard physical basis (and if the relevant input data could somehow be obtained), would be by orders of magnitude too slow and too computationally expensive for the task in hand. But standard physics is of no help also because its theories seem not to address cuts through reality of the right sorts and dimensions, so that, even if exact solutions to standard physical equations could be derived, it would in general be impossible to extract therefrom the intuitive information relevant to further action. Hayes, accordingly, sets himself the task of laying down the axioms of a theory of just those properties and relations which structure the domain of normal or average or typical human experience for human beings do, after all, seem to have the capacity to negotiate salad bars in ways which suggest that they have somehow solved the problems of data-gathering and interpretation that here arise.

Hayes' goal, as we said, is a complete theory of commonsensical reality. Thus he is not willing to sacrifice the scope and detail of his theory for the sake of hasty implementation in the form of running programs which are as experience shows destined to collapse when the attempt is made to extend them to cope with new domains of problems. His project is hereby set in opposition to the small axiomatic theories of limited domains which were characteristic of the 'toy worlds' approaches once customary in artificial intelligence research. (It would be set in opposition also to the approach of Gardin and Meltzer mentioned above.) Indeed Hayes argues that the axioms of his theory would require of the order of 10^4 to 10^5 predicates for complete expression. These predicates can, however, be divided into various sub-clusters, representing tentatively and provisionally distinguishable branches of the discipline which he has in his sights. Thus in particular Hayes distinguishes sub-clusters of predicates relating to:

- places and positions
- spaces and objects
- qualities and quantities
- change and time
- energy, effect and motion
- composites and pieces of stuff.

Consider, for example, that sub-cluster which relates to places and positions. This might involve predicates coding notions such as: on, in, at, path, inside, outside, wall, boundary, container, obstacle, barrier, and so on (and note in passing the extent to which many of these notions are alien to the sorts of representations we find in standard physics). No one of the given notions as realized in Hayes' naive physics will be capable of being reduced to or defined in terms of any of the others. An adequate treatment of the predicate coding 'on', for example, would need to tie this predicate axiomatically to predicates coding notions such as friction, support, gravity, solidity, tension, load, pressure, and so on, in addition to the purely geometrical component of this notion upon which earlier research on toy worlds had normally concentrated. Moreover, each of these predicates, too, could be treated adequately only by means of axioms in which they are tied in non-trivial ways to some or all of the others. The theory of naive physics must therefore, in Hayes' eyes, be highly non-hierarchical, as contrasted with a system like Carnap's *Aufbau* (or Zermelo-Fraenkel set theory), where a very small number of primitive notions suffices for the construction of the entire edifice of the theory. The formal properties of non-hierarchical theories have, it seems, been hardly investigated, and in this sense also we may be in the dark as to the formal properties of everyday physical reality itself. There seem, however, to be important similarities between theories of the given sort and logical systems, such as those developed by Lesniewski, which allow the use of so-called 'creative definitions'.(12)

From Aristotle to Galileo

Whether Hobbs, Hayes *et al.* are correct in supposing that one can arrive in this way at a computationally efficient theory of naive physics capable of resolving problems of the sort faced in robotics, is not a question I wish here to address. It seems, indeed, to be at this stage questionable whether a *predictive* science of the more usual sort can be achieved with these methods, for reasons to be set forth below.(13) This is, however, of little importance for our purposes, since current work in naive physics is interesting and challenging already from a *descriptive* point of view, which is to say quite apart from any predictive or explanatory concerns which might be associated with it. In this and also in other respects, as we shall see, it echoes back to earlier forays in naive-physical theory on the part of Aristotle and his pre-Galilean successors.

Modern-day psychologists have indeed acknowledged the similarity between many of our folk-physical beliefs and the ideas on motion and impetus developed by thinkers such as Philoponus and Buridan still operating within a pre-Galilean framework.(14) Philosophers had traditionally assumed, with Aristotle, that man is in a certain sense in harmony with the world: the forms we find in our minds *are* the forms of things we see. As Feyerabend puts it in his "Defence of Aristotle" (1978), Aristotle does not seek deeper theories of what lies 'behind' or 'beyond appearances', for to seek such theories would be to assume that the world is not as it appears to be. Certainly there is room for error on the Aristotelian view. This relates, however, to particular perceptions only; it leaves the general features of perceptual knowledge untouched. Thus the Aristotelian or commonsensical conception 'will never concede that it is false throughout. Error is a *local phenomenon*, it does not distort our *entire outlook*. Modern science, on the other hand (and the Platonic and Democritian philosophies it absorbed) postulated just such *global* *distortions*.' (Feyerabend 1978, p. 148)

Recent psychological interest in naive physics has understandably tended to concentrate on those quaint-seeming aspects of the Aristotelian/commonsensical conception of the world which subsequent physics has shown to rest (*per impossibile*, on Aristotle's view) on systematic error. That such systematic error exists should not, however, blind us to the fact that the central principles of the Aristotelian world-view have not in this way been exposed by subsequent *physics* as erroneous.[(15)] Rather, to the extent that these central principles have been called into question at all, they have been subverted by a *philosophy* which would consign our commonsensical beliefs, *en bloc*, to the realm of systematic error.[(16)] Truth, in this way, comes to be confined at best to a reality that is 'beyond appearance', and ontology, similarly, comes eventually to be confined to the mere repetition of post-Galilean physics.

Here, in contrast, we wish to establish in broad terms which portions of the Aristotelian world-view can still properly be counted as true true of a commonsensical reality whose relation to physical reality must then of course be independently established. (This latter question does not, be it noted, arise, where common-sense beliefs are treated from a purely psychological perspective.) Thus we follow Moore in holding that the common-sense view of the world 'is, in certain fundamental features, *wholly* true'. (1959, p. 44.) Our job will be one of determining, in part under the inspiration of modern naive-physical theory, precisely which fundamental features or components of the common-sense view *are* wholly true. But it will be one of determining also how the truths in question can be seen to be compatible (after all) with the truths of physics.

Can there be a *Theory* of Naive Physics?

Not all of those who have invested philosophically in the idea of a common-sense reality would embrace the idea that a *theory* of this reality is possible in anything like the standard sense in which we have theories in, say, physics or number theory. Indeed there are those who would deny this very possibility even while emphasizing the autonomy of commonsensical experience itself. As H. L. Dreyfus puts it, echoing ideas to be found also, in different forms, in Heidegger, Merleau-Ponty and Wittgenstein:

> it just may be that the problem of finding a *theory* of common-sense physics is insoluble because the domain has no theoretical structure. By playing with all sorts of liquids and solids every day for several years, a child may simply learn to discriminate prototypical cases of solids, liquids, and so on and learn typical skilled responses to their typical behavior in typical circumstances. (Dreyfus 1988, p. 33)

The force of Dreyfus' argument here is, however, difficult to grasp; for surely something similar could be said, too, for example of the ways in which physics students learn 'typical skilled responses in typical circumstances' as they find out how to manipulate physical and mathematical equations and equipment in laboratories. Clearly this would not of itself sanction a claim to the effect that physics does not exist as theory. Hence much further argument would be needed to prove that our behaviourally relevant knowledge can exist *only* in tacit form so that the idea of a naive physics *made explicit* would be incoherent. (Something like this seems to be suggested by Augustine's remarks on time in the *Confessions*.)

One can, however, see ways in which it might be possible to put flesh on Dreyfus' suggestions concerning the resistance to theory of common sense. One might wish to argue that the appropriate theoretical account of how humans function in and find their ways about this domain must be provided not in terms of theoretical beliefs, but rather in terms of 'unintelligent' processes on the sensorimotor level. One might, that is, hold that the ways in which humans negotiate everyday obstacles are in their essence blind or mechanical, to the extent that there is nothing like a *theory* of the common-sense world present even implicitly in the corresponding bodily processes.

Even if we did not in any sense use a theory of common-sense physics in our everyday motor activity, however, we might still be in possession of such a theory on the level of belief. Indeed it seems clear that both children and adults do have the capacity to utilize naive-physical knowledge in abstract ways, which is to say independently of their engaging in the practical solution of any specific motor problems. Moreover, it is difficult to see how an account of commonsensical knowledge and action in terms of servomechanisms and the like could leave room for any theoretical explanation of our understanding of natural language; for such understanding (and indeed the very possibility of natural language itself) seems to rest essentially on a shared, systematic set of beliefs and judgments about the common-sense world, beliefs and judgments which are after all themselves capable of being formulated in natural-language terms.

A less radical suggestion has recently been advanced by Stroll (1990), in a somewhat different context, to the effect that the naive physicist or psychologist should abandon the search for a 'holistic' theory of the commonsensical domain and content himself instead, in Wittgensteinian spirit, with context-sensitive descriptions of separate cases. Stroll's arguments here recall Peripatetic criticisms of the 'abstractness' of Galileo, who was accused by his contemporaries of having constantly disregarded the single case in attempting to comprehend nature under general laws and principles.[(17)] They recall also J. L. Austin's view in "A Plea for Excuses" to the effect that common sense is so subtle that it calls for a close, piecemeal approach allowing attention to nuance and detail, rather than an all-pervasive systematic account.

One problem for Stroll and his ilk, however, is that sizeable fragments of explicit naive-physical theory have been already worked out, at different times and in different fields. These are indeed in almost every case 'descriptive' in the sense Stroll favours (thus for example in Aristotle's *Physics*, or in Husserl's *Crisis*), but they are for all that holistic, at least in the sense that they do not resolve themselves into disconnected stories and *aperçus* of the sort some Wittgensteinians favour. Moreover, as we have seen, attempts at explanatory-predictive theories along the lines ruled out by Stroll can be found in great quantities in the literature of artificial intelligence. Such attempts have, it is true, so far yielded little in the way of successful predictive engines which could even come close to approximating some small fragment of human competence. To suggest, in Strollian spirit, that the very practice of theorizing in this sphere should be abandoned, however, is to lend credence to a counsel of intellectual nihilism. Moreover, it is to foreclose on the possibility that an adequate theory of commonsensical reality might be developed whose very *failure* as an engine of prediction would throw illuminating light on the nature of this reality itself. (We shall give reasons below for supposing that an outcome of this sort is indeed to be expected.)

The Status of Naive Physics

I shall accordingly take it for granted in what follows that it is possible to construct a theory of the commonsensical world of the sort that is canvassed by recent practitioners of naive or qualitative physics. In coming to terms with recent work in artificial intelligence, however, it is important to note that practitioners in this and related fields typically embrace views as to the status of the discipline of naive physics above all in respect of its ontological commitments quite different from those to be canvassed here. In fact there are three partially overlapping groups of alternative views which can be distinguished, which we might refer to, respectively, as the *pragmatic*, the *psychological* and the *ontological* conceptions of naive-physical theory:

> *1. The pragmatic conception of naive physics*. This sees naive physics not as a matter of propositions *true of* some specific domain of 'commonsensical reality', but rather as a collection of computationally efficient rules of thumb. Naive physics might thereby be seen as a theory, of sorts, but then it is a theory conceived in purely instrumental terms, so that its putative object commonsensical reality itself would turn out to be a sort of 'theoretical entity' possessed of no autonomous status whatsoever.
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> *2. The psychological conception of naive physics.* Another set of views might be classed loosely under the heading of psychological (one might also say 'epistemological' or 'cognitive') interpretations of the naive-physical discipline. These include, *inter alia*, conceptions of naive physics as a matter of 'mental models'.(18) Naive physics, on views of this sort, is indeed a *theory,* rather than a merely pragmatically oriented collection of rules (or tacit habits) of thumb. But it is not, like physics proper, a theory of some transcendent domain. Rather, it is a sort of psychology in disguise; a science of the beliefs human beings share as concerns their everyday environment. The fact that some, at least, of these beliefs are false is of no consequence for the discipline on this perspective,

since true and false beliefs will quite properly be treated as having equal psychological reality.

3. The ontological conception of naive physics. The third set of views here distinguished sees naive physics as a theory in the limit *true* of a stable, well-delineated, precisely and naturally specifiable subject-matter of its own, distinct from that of psychology, a subject-matter properly deserving the title of 'common-sense world'. It was investigations of this subject-matter which predominated among metaphysicians and natural philosophers in the time before (and for some time after) Galileo. Here true and false beliefs about the physical environment are clearly not of equal value. Indeed the most important goal of naive physics on this conception is precisely that of finding systematic means of filtering out, from the totality of such beliefs, those which merit admission into the edifice of the theory.

Ad 1. The pragmatic conception, which predominates especially among the practitioners of artificial intelligence research, will be of little further concern. One not inconsiderable problem with the doctrine is that it has the effect of inverting our usual intuitions in such a way that tables, chairs, loaves of bread, and the like, are now to count as 'theoretical entities'. Another problem is that, like all pragmatic doctrines, it tells us at most part of the story. What it does not and can not tell us is *why*, given two or more competing realizations of the naive-physical discipline, it should be the case that one is more or less useful or effective than the others. It is, again, a counsel of intellectual nihilism to deny the possibility of and the necessity for deeper questions here, questions which will yield reasons both for differing levels of intuitive adequacy and for computational or predictive success or failure.

Ad 2. Research in naive physics falls, on the psychological conception, within the domain of experimental psychology as standardly conceived, or within some neighbouring domain such as that of cognitive anthropology. One can, for example, investigate the naive-physical beliefs of children in light of the ways in which such beliefs come gradually to be modified or corrected on exposure to the Newtonian world-view encapsulated in standard physics textbooks.[(19)] Or one can investigate the extent to which non-Newtonian beliefs about the physical world are tacitly retained even by those adults who are otherwise able to demonstrate a capacity to affirm the correct Newtonian principles.[20]

There is surely a sense in which investigations of these matters may be useful and illuminating. One problem for us here, however, is that, when once this psychological (anthropological, developmental) perspective is taken seriously, it might appear difficult to justify talk in terms of some one single discipline of naive physics at all. For there seems to be a large number of different systems of naive-physical beliefs manifested among different groups of human subjects at different times and places. Not merely is there an opposition between children's and adult physics; there seems to be a diversity in physical beliefs also as between different cultures, to the extent that some have been led to conceive psychological naive physics as collapsing into a structureless mass of belief-systems manifesting limitless variety through time and space. Certainly if one looks for evidence to support a view of this sort, given the wealth of extant conceptions of the nature of reality in different cultures, one will undoubtedly find it. Much valuable work has indeed been done, in the area of what might be called 'ethnophysics', on the multiplicity of naive-physical belief-systems that have arisen in the course of human, perhaps even of animal, history.[21]

It would be wrong, however, to assume as it were *a priori* that there can be no constraints on such diversity. Thus one should not suppose that wherever one has a systematic difference in behaviour one has therefore also a difference in what ought properly to count as the naive physics governing such behaviour. One may merely have a case of widespread error. It seems for example that there is a widespread misconception, at least among Americans, as to the workings of thermostats. This fact should not, however, be taken to imply that those who hold false beliefs about thermostats thereby manifest a non-standard naive-physical 'theory of heat', as for example Kempton (1987) seems to hold. From our present perspective there can be no common-sense theory about thermostats, any more than there can be a common-sense theory of osmosis or radioactive decay. Thermostats are, naively speaking, boxes which control the heat. Theories or popular prejudices which go beyond this naive basis do not belong to common sense, and can therefore lend no support to the idea that common sense is itself subject to massive diversity in the relevant respect.

Ad 3. It is the third (ontological) conception of naive physics that will be defended here. Underlying this conception is the idea that it is possible to formulate principles which will enable one, gradually, to remove errors and other foreign matter from the class of those beliefs that are relevant to the construction of a true naive-physical theory. Such principles give us a means of coping with the supposed diversity among folk-physical belief-systems, so that the common-sense world with which the ontological conception operates would be, in the limit, independent of variations in belief.

A parallel intuition is defended by those for example the so-called 'Southern Fundamentalists'[(22)] who give credence to the idea that our everyday psychological beliefs, too, constitute a *bona fide* system of truths. Indeed each of the physical issues dealt with here seems to have an exact equivalent in the issues addressed by philosophers and others under the heading of 'folk psychology'.[(23)] There, too, one finds a wide variety of beliefs that have been maintained by human beings at different times and places. The existence of false beliefs about the mind does not of itself, however, imply that it is impossible to disengage therefrom some core of primary folk-psychological beliefs beliefs which might be true and claim a truly scientific status.

Similarly, I shall claim, the existence of more or less folksy physics is not of itself a sufficient warrant for rejecting the idea of a (true) naive physics more strictly conceived. Moreover if, as some hold, it is a worthy project to attempt to prune away the more folksy bits of common-sense psychology in order thereby to establish, as far as is possible, the laws governing the mental domain of beliefs and desires, then it ought, surely, to be a no less worthy project to attempt to prune away the more folksy bits of common-sense physics in order to establish the laws governing that domain of commonsensical things and events to which such beliefs and desires primarily relate. The dominance of the psychological and epistemological orientation among modern philosophers is indeed poignantly revealed in the extent to which questions of the given sort have been taken seriously as far as folk psychology is concerned, where their folk-physical counterparts have been virtually ignored.

Naive Physics is True

The anthropologist Robin Horton has drawn what is for our purposes a useful distinction between what he calls 'primary theory' and the different sorts of 'secondary theories' which are, he argues, characteristic of different economic and social settings.

Primary theory or what we have been calling 'common sense' is, as Horton points out, developed to different degrees by different peoples in its coverage of different areas. In other respects, however, it differs hardly at all from culture to culture. In the case of secondary or 'constructive' theory, in contrast,

> differences of emphasis and degree give place to startling differences in kind as between community and community, culture and culture. For example, the Western anthropologist brought up with a purely mechanistic view of the world may find the spiritualistic worldview of an African community alien in the extreme. (1982, p. 228)

This agreement in primary theory has evolutionary roots:

> there is a sense in which such theory must 'correspond' to at least certain aspects of the reality which it purports to represent. If it did not so 'correspond', its users down the ages could scarcely have survived. At the same time, its structure has a fairly obvius functional relationship to specific human aims and to the specific human equipment available for achieving them. In particular, it is well tailored to the specific kind of handeye coordination characteristic of the human species and to the associated manual technology which has formed the main support of everyday life from the birth of the species down to the present day. (op. cit., p. 232)

Where, then, from the perspective of survival, we can believe what we like concerning micro-spirits and macro-devils residing on levels above or below the levels of everyday concern, we have been constrained as far as the broad physical structures of everyday reality are concerned, to believe the truth otherwise we would not be here.[(24)]

It seems, indeed, to be the case that the commonsensical world is apprehended in all cultures as embracing a plurality of enduring substances possessing sensible qualities and undergoing changes (events and processes) of various sorts, all existing independently of our knowledge and awareness and all such as to constitute a single whole that is extended in space and time. This body of belief is put to the test of constant use, and survives and flourishes in very many different environments. No matter what sorts of changes might occur in their surroundings, human beings seem to have the ability to carve out for themselves, immediately and spontaneously, a haven of commonsensical reality. Moreover, our common-sense beliefs are readily translated from language to language and judgments expressing such beliefs are marked by a widespread unforced agreement.

Common-Sense Theory and Physical Science

Ever more pressing, now, is our question as to the relation of naive physics to physical science of the standard quantitative sort. Here, too, a range of variant conceptions can be distinguished. At one extreme is a view according to which commonsensical reality would itself be the only reality there is, so that standard physics would have to be understood in instrumental terms, as secondary to and derivative of the science of commonsensical reality. (There are traces of this view in Husserl's *Crisis* where we find also an important anticipation of Horton's ideas on primary and secondary theory.)

Between this and the opposite extreme position which sees naive physics as simply false a position we have already had occasion to dismiss above is a family of emergentist views, according to which both commonsensical and standard physical reality are awarded an autonomous existence of their own, the former being seen as a matter of higher-level stable features of the latter. Such views parallel in some respects the view of minds as higher-level features of brains that has been defended most recently by Searle. Just as mind is, in Searle's terms, 'caused by . . . and realized in' certain portions of physical reality,[(25)] namely in the operations and structure of the human brain, so commonsensical reality would be caused by and realized in that portion of physical reality which constitutes our external environment. Both mind and commonsensical reality are from this point of view perfectly autonomous objects of theoretical concern; both, however, are such that there are limits on the sorts of theory which they are able to support. Above all, as we shall see, commonsensical reality is not able to support the sort of predictive theory which we enjoy in regard to cuts through physical reality at certain lower levels.

Physics of the Common-sense World[26]

How, then, are we to select from the totality of structures of the physical world those precisely relevant to the level of naive physics as here conceived? We draw attention, first of all, to the ubiquitous role of sensible qualities in filling out the world of commonsensical experience. The sensible qualities of objects can in every case be identified with the properties of certain corresponding *physical variations*. Thus colours, for example, can be identified with surface spectral reflectances,[27] the qualities of hot and cold with certain properties of the movements of molecules, and so on. Only some types of physical variation are able to support phenomena of the qualitative sort. Simple mechanical systems (pendulums, for example) fall out of court in this regard, even though they may *cause* properly qualitative variation in other media (for example in the air molecules which they set in motion). How, then, are we to focus in on variations of the relevant sort? Here the key idea, which has been set out in greater detail in the papers by Petitot referred to in the list of references below, is due to René Thom. How can physical theories be enriched sufficiently to capture in scientific fashion the features specific to qualitative reality? The ground of a solution lies already in the fact that physics, for all that it is restricted to the quantitative, does indeed deal with the phenomena from out of which the qualitative world is composed. What it does not do is to deal with those specific ways in which these phenomena are composed or knitted together or are delineated from each other that are relevant to the world of our qualitative experience. It is in showing how to fill this gap that Thom's achievement lies.

Whatever appears, appears in the context of a spatio-temporally extended whole. There is, in other words, a relation of foundation or existential dependence between sensible qualities and spatio-temporal extension (no colour can, as a matter of necessity, exist without spatial extension, no sound without duration, etc.).[(28)] The perceived qualities of a black and brown spotted dog, for example, have a certain spatial extension. The qualities distributed across any given extension are in addition either fused together phenomenally, in the sense that there is no observable separation between them (as when for example there is a smooth transition from one colour to another); or they are phenomenally 'separated'. In the former case the underlying physical variation is continuous, in the latter case it manifests a certain sort of discontinuity.

Note that in the case of the spotted dog there is from our present perspective no intrinsic difference between the separation or apparent contour which corresponds to the perceived exterior of the dog and the separation which occurs at those perceived interior boundaries where spots are set apart from their surroundings. Indeed it seems clear in relation to either sort of case that a sensible phenomenon is set into relief in relation to other phenomena precisely where a discontinuity has been created by the qualitative moments which fill its extension. It is *separation*, in other words, which accounts for *salience*.

In giving an appropriate mathematical expression to this idea we suppose, with Thom and Petitot, that W is the spatio-temporal extension of a given phenomenon. As a portion of space-time, W is a topological space with the usual topology. Suppose further that the different qualities which fill W are expressed by degrees of *n* distinct intensive magnitudes $q_1, q_2, \ldots, q_n$, each a function of points w W. The $q_i(w)$ are then sensible qualities (colour, texture, temperature, reflectance, etc.), but considered physically, [(29)] as immanent to the objects themselves and as associated with a certain possibility of measuring.[(30)]

A point w is called *regular* if all the $q_i(w)$ are continuous in a neighbourhood of w. Let R be the set of regular points of W. R contains a neighbourhood of every one of its points, and hence it is an open set of W. Let K be the complementary set of R relative to W. K is the closed set of what we can call the non-regular or *singular* points of W. Clearly, w is a singular point if and only if there is at least one quality q_i which is discontinuous at w. We shall call K the *morphology* of the phenomenon that fills W. We shall now argue that K is the system of qualitative discontinuities which sets this phenomenon into relief and makes it salient as a phenomenon. (Consider, for example, the morphological organization of a leaf, of a crack in a window-pane, of a dog, or of a photograph of a dog.)

In order to accord physical content to this definition, we must find some way to conceive a morphology K as a matter of physical properties internal to whatever underlies or causes the phenomenon in question. Condensing a lot of physical detail into a small space, we can say that the instantaneous states of a physical system *qua* physical are, when taken individually, *transient*: they are too fleeting to be observable. There are however circumstances in which there arise effectively observable states of a system: this occurs for example where trajectories manifest asymptotic behaviour, or where there is sufficiently rapid oscillation between one stable endpoint and another. Such effectively observable states, the states into which the system repeatedly falls, or into which it tends to fall, are for obvious reasons called the *attractors* of the system. Consider, for example, an oscillating electric circuit. From any initial state the system after some time reaches the stable oscillatory state and so its trajectory is attracted by this state.

Return, now, to our phenomenon of the spotted dog having substrate S, spatio-temporal extension W and morphology K. Choose a non-singular w W. The internal state of the substrate S at w can be physically described in terms of some attractor A_w of some 'internal' dynamics. And the $q_i(w)$ are intensive quantities associated with A_w. To explain the qualitative discontinuities of the $q_i(w)$, we now let w_o K be some singular point within W. In moving through points w W the attractor A_w becomes unstable when we cross w_o and is replaced by another attractor B_w. Similarly when we cross the exterior apparent contours of things the attractor A_w disappears entirely. Note, in all of this, that the behaviour of the underlying physical system (the relevant variations themselves) are unobservable. What we experience as salient, and what we possess words in natural language to describe, is the qualitative discontinuity which is the phase transition.

One incidental outcome of this account is that, exactly in keeping with the common-sense perspective outlined above, it removes the justification from Locke's thesis to the effect that the secondary qualities of things are inherently subjective. Certainly there is a distinction between the physical structures which are, respectively, the primary and secondary qualities of things given in experience.(31) This distinction does not, however, lie in any supposed 'subjectivity' of the latter, as Locke and many others have believed.(32) Rather, it lies in the fact that secondary qualities are not of interest from the point of view of physical theory because they do not play any important role in the causal structure of the world independent of their role in perception. They reflect delineations in physical reality of a kind whose interest depends essentially on the existence of a certain perceptual apparatus on the part of human perceivers. They are not, though, dependent on specific perceptions or beliefs (nor, *a fortiori* on our languages or theories). As Hilbert writes:

> All that is necessary for the objectivity of a property is that objects have or fail to have that property independently of their interactions with perceiving subjects. Color is objective in so far as the colors of objects do not depend on how they appear to observers, or even whether or not there are any observers . . . Although reflectance is an objective property in this sense and is physically well understood, it is not reducible to more fundamental physical properties. (1987, p. 120f.).

Note that one incidental implication of the thesis that naive physics is true, is that the world of commonsensical reality will turn out to exist independently of human experience: palaeontology and other related disciplines do after all describe the common-sense world as it was before there were people. Of course this world would not be interesting if there were no people, and so these disciplines, too, would not exist. But what the disciplines describe is, nevertheless, such as to *exist* independently of human beings.

A Theory of the Common-sense World

Our goal is that of providing a sound theory of that autonomous domain which most properly deserves the name of 'commonsensical reality'. Our ontology of qualitative reality can be taken only as a first step along this road. On the one hand the realm of qualitative reality is too wide, since it extends beyond the domain of commonsensical experience, for example in including colour-like qualitative structures outside the domain of what human sensory organs can detect. To correct the qualitative ontology we need to turn to the psychology of sensation in order to establish the limits of qualitative structures graspable by the human sensory system. On the other hand our account is too narrow, since it fails to do justice to those dimensions of ontological form which are embraced by the world of commonsensical experience but which are skew to the strictly qualitative sphere. Thus there remains the task of supplementing the qualitative ontology with a theory of such commonsensical categories as those of substance, of change or process, of typicality, species and categorization, of places and times, and so on. As in our account of the qualitative ontology, so also here, what matters are certain sorts of perceptually detectable (salient) boundaries which are present in the underlying physical reality, boundaries which are not addressed in quantitative physical theory. The doctrine of emergence that is hereby implied is accordingly one of the emergence not of *things* but of *boundaries* or *contours.*

From the work of Thom and Petitot we already know enough about the theory that will result hereby to know that it will have a power of prediction that is imperfect as compared to that of physics proper. Naive physics seeks only to fix the repertoire of qualitative and structural forms involving substance, accident, change, etc. which make up the world of everyday experience. And then it turns out that there is a restricted number of such forms into which the behaviours of complex systems can typically fit. What it cannot do is tell us when or where this or that form will come to be instantiated. For unlike standard physics, which applies, in its fashion, to everything, and therefore (if at certain restricted granularities only) leaves no predictive-explanatory gaps, naive physics deals with a narrow range of phenomena the explanation-prediction of which must in almost every case involve phenomena outside this narrow range. This makes it highly doubtful whether naive physics could ever serve the needs of artificial intelligence research for example in the sphere of robotics and elsewhere. Nonetheless, however, it is with the help of true naive-physical beliefs that human beings are able to find their stumbling way around the world, just as it is with the help of naive psychological beliefs that they are able to make normally reliable predictions about the actions of their fellows.

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Endnotes

1. 1. Thanks are due to R. Casati, V. Gadenne, J. Petitot, H. Philipse and J. Seifert for helpful comments.

2. 2. See especially Thom 1988, Petitot 1985.

3. 3. See Kanizsa 1979 and Bozzi 1958, etc.

4. 4. Cf. Gibson 1979 and also Stroll 1988, in which the ontology of surfaces, conceived on broadly Gibsonian lines, is for the first time worked out in detail.

5. 5. Cf. Rosch *et al*. 1976, Keil 1979.

6. 6. See on this also Forbus 1983, 1984, 1985, Kuipers 1986, Weld and Kleer, eds., 1989.

7. 7. Cf. Gardin and Meltzer 1989.

8. 8. Gravity, for example, is stored as a tendency for an element to move in a certain direction by a distance that is determined by a parameter coding the intensity of the force applied. See Gardin and Meltzer 1989, p. 143, citing Gambardella 1985.

9. 9. Hobbs, *et al*.; Hager 1985.

10. 10. Hobbs, *et al.*

11. 11. I ignore, here, the considerable technical difficulties which would have to be overcome in order to construct the necessary hardware.

12. 12. See Rickey 1975.

13. 13. See also McDermott 1990, who rightly criticizes Hayes' 'logicist' assumption to the effect that it is by means of deductions from axioms that we use naive physics to find our way around the world. There are other central aspects of Hayes' work to which one could object. Thus for example the account of the ontology of liquids presented in Hayes 1985a is flawed in virtue of the fact that it rests essentially on the highly non-commonsensical (Quine-inspired) trick of reducing objects to four-dimensional histories. As R. Casati has shown in as yet unpublished papers, this leads to highly counter-commonsensical consequences.

14. 14. See especially the papers by Bozzi listed below, and more recently also e.g. McCloskey 1983a, Holland, *et al.* 1986, p. 208.

15. 15. Thus Aristotle was perfectly clear, for example, that solid bodies will fall towards the centre of the earth if not impeded in their fall.

16. 16. Thus for example the corpuscular philosophers held that the majority of our ordinary perceptual judgments 'must be <u>literally false</u>, because the redness or the warmth we think we perceive are not really the qualities or states of material things we take them commonly to be.' (Cf. Philipse 1989, p. 143.)

17. 17. Cf. Bozzi, 1958, p. 2f. of translation.

18. 18. See e.g. Gentner and Stevens, eds. 1983.

19. 19. See e.g. Shanon 1976, Peters 1982, Clement 1982, DiSessa 1982, Kaiser, Jonides and Alexander 1986, Roncato and Rumiati 1986.

20. 20. As McCloskey puts it in regard to the 'remarkably well-articulated naïve theories of motion' people develop on the basis of their everyday experience:

theories developed by different individuals are best described as different forms of the same basic theory. Although this basic theory appears to be a reasonable outcome of experience with real-world motion, it is strikingly inconsistent with the fundamental principles of classical physics. In fact, the naive theory is remarkably similar to a pre-Newtonian theory popular in the fourteenth through sixteenth centuries. (1983, p. 299)

See also p. 318 on the remarkable persistence of folk theory in the face of formal physics training, as well as McCloskey 1983a, McCloskey *et al*. 1980, and Forguson 1989.

21. 21. Köhler's 1921 is to no small part devoted to the naive physics of chimpanzees. Köhler argues above all that there is practically no *statics* in the chimpanzee, and he notes that something similar holds, too, of very young children. See also Lipmann and Bogen (1923), an experimental study of human naive physics by students of Köhler in Berlin.

22. 22. Cf. Graham and Horgan 1988. See also Forguson 1989 on 'rational psychology'.

23. 23. This is clearly brought out in D'Andrade 1987, which incidentally reveals also the remarkable similarity between folk-psychological models and the work of traditional philosophers on the structures of mind.

24. 24. We cannot, however, use the theory of evolution to provide a proof of common sense. For this theory, like all developed scientific theories, rests on evidence whose interpretation itself presupposed the truth of common sense.

25. 25. Searle 1983, p. 265. Note, however, that the precise meaning of phrases like 'realized in' remains in need of detailed elucidation, elucidation which Searle himself seems not to see the necessity of providing.

26. 26. The ideas in this section are due to Jean Petitot.

27. 27. Hilbert 1987.

28. 28. See the papers collected in Smith, ed., 1982, and also Husserl's third Logical Investigation.

29. 29. Certain simplifications are involved here. Thus there is no single property of surface spectral reflectance, which is a macroscopic approximation of a more fine-grained system on the quantum level of a range of properties having to do with the emission-absorption spectra of the atoms constituting the substrate.

30. 30. Note that, since colour is dissective only to a certain extent, one should strictly speaking speak of colour not at a point but over an interval; this adjustment does not affect the validity of the account put forward in the text however.

31. 31. On the nature of these differences, and on the manifold varieties of secondary qualities in general, see Witschel 1961 which summarizes Husserl's position.

32. 32. Note that this account, which is derived from Hilbert 1987, is distinct from that of Thom/Petitot, which sees colours is being merely associated with certain underlying physical qualities, not as identical therewith.