Naive Physics: An Essay in Ontology[1]

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From: *Philosophical Psychology*, 7/2 (1994), 225-244.

Introduction

In the works of Aristotle or of the medievals, as also in the writings of later common-sense philosophers such as Thomas Reid or G. E. Moore, we find a family of different attempts to come to grips with the structures of common sense and of the common-sense world that is given to us in normal, pre-theoretical experience. We shall argue in what follows that the theory of such structures provides an important and hitherto unappreciated link between early Gestalt psychology on the one hand and contemporary developments in philosophy and in artificial intelligence research on the other.

The notion of providing an adequate theory of the common-sense world has been taken seriously of late above all by those, such as Patrick Hayes or Kenneth Forbus, who see in such a theory of what they call 'naive' or 'qualitative physics' the foundations of future practical successes in robotics.[2] This naive physics is, however, like cognitive science in general, in a state of flux, and a serious philosophical investigation of its presuppositions and achievements has hardly been attempted. Yet it is already at this stage possible to point to a certain apparent defect or one-sidedness of current research in this field that is due to the predominant assumption that it is set theory and related instruments of ontology that are to provide the basis for naive-physical theorizing. The defect arises, we shall suggest, in virtue of the fact that naive physicists working in the A.I. sphere are for obvious reasons concerned with certain specific sorts of formal implementations. Their motivations are in the first place pragmatic, and so their aim is not so much a theory of the common-sense world that could be defended as being *true,* but rather a theory that has certain sorts of practical advantages from the point of view of implementation. Both of these factors, we shall argue, lead the naive physicists to neglect important detailed contributions to the theory of common sense that have been made by both psychologists and philosophers, contributions which it will be the business of the present paper to describe.

What will be surprising to those who are acquainted mainly with the standard artificial intelligence literature on the topic of naive or commonsensical physics is the extent to which it is among the Gestalt psychologists, above all, that some of the most important and original work in this respect is to be found. Indeed one could argue that the Gestalt-theoretical approach to external reality is in its entirety a variety of naive physics, something which is brought out clearly for example in the pronouncements of Wolfgang Köhler to the effect that there seems to be ‘a single starting point for psychology, exactly as for all the other sciences: the world as we find it, naïvely and uncritically’. Our naive experience, as Köhler points out, ‘consists first of all of objects, their properties and changes, which appear to exist and to happen quite independently of us’ (1947, p. 1, 2). We can compare, on this very issue, Gibson:

> Some thinkers, impressed by the success of atomic physics, have concluded that the terrestrial world of surfaces, objects, places, and events is a fiction. They say that only the particles and their fields are “real” . . . But these inferences from microphysics to the perception of reality are thoroughly misleading. The world can be analyzed at many levels, from atomic through terrestrial to cosmic. There is physical structure on the scale of millimicrons at one extreme and on the scale of light years at another. But surely the appropriate scale for animals is the intermediate one of millimeters to kilometers, and it is appropriate because the world and the animal are then comparable. (1966, p. 21f)

It is this intermediate world, the world of common sense, which will be our concern in what follows.

I. GESTALT THEORY AND THE HISTORY OF NAIVE PHYSICS

Avenarius and Mach

A full treatment of *theories* of common sense would have to deal with Aristotle and the Scholastics, with work on early physics in the spirit of Pierre Duhem, with Galileo’s presentations of the received physical theory he then criticizes, with Thomas Reid and the Scottish school of common sense. Our story, however, shall begin with Richard Avenarius and Ernst Mach, both of whom explicitly sought a view of the world as this is directly given in perception. More precisely, Avenarius and Mach operate with a notion of ‘pure perceptions’, which is to say, perception conceived as having been stripped of those metaphysical ingredients (for example ideas about absolute space and time) which, as they conceived matters, are illegitimately imported into our experience. The ‘natural concept of the world’, on Avenarius’ view, ‘is that general concept we all have about the world in its entirety before any exposure to philosophy’:

> Intrinsic to the natural concept of the world is the unshaken belief that all the component parts of my environment exist and develop, change or remain constant, in interaction with one another, in some form of stable regularity, all independently of my observing them or not observing them. (Scanlon 1988, p. 220f.)

The matter was approached from another, complementary standpoint by Mach, who sought to found the science of physics on a purified world-view along lines similar to those considered by Avenarius to show how physical science can grow, as it were organically, out of common-sense experience. Mach's ideas in this respect formed part of the background of Einstein's work on the theory of relativity, but the biological approach to knowledge which Mach and Avenarius shared the idea that *theory* should evolve naturally from out of the ground of ordinary experience anticipated also the work of the Gestalt psychologists and certain aspects of the ecological ideas we find in Gibson.

Like all their forerunners, however, neither Mach nor Avenarius has any notion of a *separate discipline* of naive physics of the sort that is at issue in current artificial intelligence research. Moreover both allowed their respective images of reality to become infected with doctrines of elementarism and of neutral monism of a metaphysical sort. Thus their attempts to protect their views of 'pure perception', etc., against alien impurities were not, in the end, completely coherent.

Köhler, Lipmann, Bogen

Wolfgang Köhler was influenced both directly and indirectly by Mach,(3) and it is in fact in the correspondence of Köhler that there appears what is perhaps the first occurrence of the term 'naive physics'.(4) In his *The Mentality of the Apes*, a work whose original German text dates back to 1917, Köhler points out that

> psychology has not yet even begun to investigate the physics of ordinary men [*Physik des naiven Menschen*], which from a *purely biological standpoint*, is much more important than the science [of theoretical physics] itself (Köhler 1921, p. 149).

As Köhler makes clear:
not only statics and the function of the lever, but also a great deal more of physics exist in two forms, and the non-scientific form constantly determines our whole behaviour. (With experts, of course, this is saturated in all stages by physical science in the *strict* sense.) (Köhler, *loc. cit.*)
Köhler's ideas were worked out in detail in application to the different levels of intelligence manifested by school-children by the Berlin Gestalt psychologists Otto Lipmann and Hellmuth Bogen in a work entitled *Naive Physik*, published in 1923. The latter comprises first of all a theoretical investigation of the nature and scope of naive physics itself, which is seen by Lipmann and Bogen as a capacity for intelligent action in relation to everyday tasks and objects. There follows then

a summary of the results of experimental work on naive-physical beliefs about causality and natural law and on the relation between such beliefs and corresponding actions of children of different levels of intelligence.

Interestingly, Lipmann and Bogen see naive physics as a true, and therefore useful, discipline. Thus they argue that children should be trained in naive physics (where many later psychologists have been interested, rather, in those naive-physical beliefs which stand out as being *false).*[(5)]

Gibson

J. J. Gibson's investigation of the world of basic affordances for human action consists in the attempt to establish a new descriptive standpoint which would pick up 'facts at a level appropriate for the study of perception'. Such a level is *prima facie* set against standard mathematical physics and related disciplines which are concerned with 'the atomic and cosmic level of things' and leave out everything in between.[(6)]

Gibson, however, is confident that these intermediate level facts 'are *consistent* with physics, mechanics, optics, acoustics, and chemistry', being only 'facts of higher order that have never been made explicit by these sciences and have gone unrecognized'. (1986, p. 17) Hence in contrast to the position of Galileo or Locke as concerns the world that is given in common-sense experience it is possible to develop a *realist* theory of the given facts, and this in a manner which does not involve the rejection of standard quantative physics. Gibson terms 'ecology' the discipline that should encompass these higher-order facts; it is presented as 'a blend of physics, geology, biology, archeology, and anthropology, but with an attempt at unification' on the basis of the question: what can stimulate the organism? (1966, p. 21)

Gibson acknowledges a 'debt to the Gestalt psychologists, especially to Kurt Koffka' whose ideas in shaping this new, intermediate level of description Gibson sees himself as having extended (in this connection he mentions also Katz, Michotte, Hochberg, Metelli and Johansson). This Gestaltist setting shows up most interestingly in Gibson's *nomenclature for surface layout*, whose basic concepts we shall meet again in our thematic section below. These concepts apply to what Gibson calls *surface geometry*, a discipline which stands to naive physics in something like the same relation in which the more familiar varieties of abstract geometry stand to physics in the standard quantitative sense.[(7)]

The Austro-Italian School of Gestalt Theory

In some respects parallel to the Berlin Gestalt tradition of Köhler and Wertheimer is the work of the Graz school around Alexius Meinong (under whom Ehrenfels had studied in Vienna). Meinong's own "On the Origins of our Knowledge in Experience" of 1906 contains ideas on the world of external perception which then influenced Fritz Heider's work on "Thing and Medium" to be discussed below. The Graz school was translated through Meinong's assistant Vittorio Benussi to Italy, where subsequent generations of Gestalt psychologists have made a number of serious contributions to our problem.(8)

Some of the very first *experimental* work on naive physics was performed by the Italian Gestaltist Paolo Bozzi in the late '50s, in a manner which recalls earlier work by Michotte on the perception of causality. Bozzi's subjects were asked to select, from a range of more or less artificially constrained cases, which movement of a pendulum looked most natural. As he recalls in his autobiographical book *Naive Physics*,(9) such experiments were partly inspired by a study of the naive conceptions of the Aristotelian spokesman Simplicio in Galileo's *Dialogue*, Bozzi's idea being that these earlier 'naive' views of physical reality reflect or are influenced by the ways in which we are disposed perceptually to organize the physical reality we see.(10) There is, according to Bozzi, a holistic interwovenness of experienced qualities of objects and of certain physical conceptions we have of them. Qualities such as force, agency, resistance, harmony, equilibrium, etc. can thus be seen to play a primary role in perceptual organization.

Phenomenology

The phenomenologists, too, concerned themselves in systematic ways with the idea of a science of common-sense experience. As the cultural anthropologist R. M. Keesing points out (1987, p. 375): 'much of phenomenology (Husserl, Schutz, Heidegger, Merleau-Ponty) is precisely about models of everyday cognition'. Further, it is well known that there was an important interplay, both personal and theoretical, between the phenomenological and Gestaltist movements, whose respective members shared also a wide spectrum of common sources. Our investigations here will to some extent be concentrated in the areas of this interplay and more precisely still in relation to the work of Husserl, Schapp and other early phenomenologists. A complete treatment would however need to consider also the important contributions of Merleau-Ponty and of Heidegger to our understanding of the phenomenology of common sense.

It is Husserl's *Crisis of European Sciences*, above all, which addresses in explicit philosophical fashion the problem of the relation between the ontology of the common-sense world called by Husserl the 'theory of the structures of the life-world' and pre- and post-Galilean physics. As Husserl points out (*Crisis*, p. 65), one reason for the neglect of the naive and of the commonsensical in the history of philosophy has been that, due above all to the influence of Plato, philosophy wanted always to be *episteme*, and not *doxa*, turning up its nose at the latter not merely because it is unscientific but also (with less apparent justification) because it is not itself capable of serving as the *object* of a scientific treatment. The task of phenomenology, now, Husserl sees as being that of harmonizing the naive and the exact (of understanding the relation between the common-sense world and its various outgrowths and extensions in particular in the realm of science). In our thematic treatments of different sub-areas of naive physics below we shall return to Husserl's view of things, cause and change, and consider also the contributions of other thinkers on the borderlines of phenomenology and Gestalt psychology to our understanding of the detailed structures of naive-physical reality.

II. NAIVE PHYSICS AND ARTIFICIAL INTELLIGENCE

Historical Antecedents

The basic approach of the A.I. naive physicists is to take a sampling of deductive inferences from a given domain and to see how formal languages can be developed in which the relevant knowledge can be axiomatically expressed and the relevant inference procedures formally captured. Such work has historical antecedents in the so-called 'mathematical philosophy' that was initiated by Whitehead in a ground-breaking paper entitled "On Mathematical Concepts of the Material World" and published in 1906. This mathematical philosophy was then pursued in some of the early writings of Bertrand Russell, but it was developed most systematically by Stanisaw Leniewski and his disciples, in Poland and elsewhere, who constructed a range of precise and rigorous formal-ontological theories of those general concepts which lie at the heart of common sense concepts such as time, space, part, whole, relation, quality, and so on. These include the formal theories of part and whole developed by Leniewski himself;[(11)] the work of Karl Menger Jr. on naive topology, of Carnap, Becker, Nicod, etc. on the relation between 'physical' and 'intuitive' geometry and on the question as to whether visual space is or is not Euclidean in structure. They include the investigations of Eino Kaila, which seek to establish the specific nature of the properties appropriate to each of the three domains of 'sensory phenomena', of 'physical bodies' and of 'physico-scientific reality' and which draw not only on Carnap and others in the Vienna Circle but also on Köhler.[(12)] And they include the formal theories of temporal and biological concepts developed by Woodger, and the various systems of realistic formal ontology that have been developed on a Leniewskian or Husserlian basis in subsequent decades. Such theories have left their mark, in different ways, on the corpus of literature in analytic philosophy and logic upon which the A.I. naive physicists have drawn. Yet the original version sof these theories have been largely neglected because they do not fall squarely within the Frege-Russell-inspired logical tradition which the A.I. community, for reasons hinted at above, has taken as its standard. Most importantly, they differ from the Frege-Russell tradition in adopting as the basis of their formal-ontological theories not the abstract and mathematically problematic theory of sets but rather the simple and more commonsensical theory of parts and wholes or 'mereology'.

Critique of Artificially Intelligent Naive Physics

The work of the Gestaltists, of Gibson, and of the early phenomenologists has the aim of providing an adequate realist theory, a *science* or *ontology* of the common-sense world which will be consistent in principle with sophisticated theories of cognition and of standard physical reality. Such work presupposes that there is, as it were, a stable intermediate level or region of reality which it is possible to describe, realistically, within the framework of a rigorous theory.

When we turn to the field of artificial intelligence, however, then we find that there are at least three distinct aims which have determined the nature of the relevant research, and this in ways which bear witness to an important equivocation in the notion of 'common-sense reasoning' which lies at the heart of the A.I. programme. For common-sense reasoning can mean:

(1) formally rigorous and precise reasoning about the world of common sense (reasoning on the properly theoretical level about the world that is grasped pre-theoretically);

(2) reasoning as actually practised by humans in their everyday, non-theoretical lives;

(3) a philosophically motivated *reconstruction* of either (1) or (2).

Sadly, the manifest tension between these three conceptions is far from having been successfully resolved in the A.I. literature. For each gives rise to a different sort of aim on the part of those engaging in naive-physical research:

(1) gives rise to a drive toward a realistic formal ontology, toward precise and rigorous theories of the concepts at the heart of common-sense, such as have been attempted in different ways by Hayes *et al*. and by formal ontologists in the traditions of Lesniewski, Husserl[(13)] or Thom[(14)];

(2) gives rise to the desire to *simulate* everyday reasoning i.e. to construct inference-engines which would reconstitute in the computer precisely that lack of sophistication which is characteristic of our commonsensical thought-processes;

(3) gives rise to the drive to reconstruct some more or less simplified analogues of the relevant families of commonsensical concepts on the basis of non-commonsensical but logically more tractable notions imported from elsewhere.

Our aim, here, is to sketch the history of naive physics concentrating especially on attempts to produce realistic theories of the naive-physical world. As the work of Hayes, above all, makes clear, this drive towards realistic theory is certainly present in the A.I. literature. It is illustrated, for example, in the following passage from a recent textbook on common-sense reasoning and naive physics by Ernest Davis, who points out that certain otherwise attractive primitives have to be rejected from A.I. theories because:

> They do not correspond to anything much in the real world; they are arbitrary distinctions made by us, as theory builders, for the purpose of making axioms cleaner and shorter. As a result, our representation becomes less a description of the relations in the world and more a matter of logic programming. (1990, p. 206)

On the other hand however, and in conflict with this realistic drive, is first of all the desire of AI research on common sense to achieve faithfulness to common-sense *reasoning* via the development of theories which would themselves employ inference-patterns mimicking those of common sense. Yet the latter is clearly not precise and rigorous, and it seems clear that a sophisticated theory of the common-sense world (or indeed of common-sense reasoning) can be produced only in ways which involve going beyond those crude processes of reasoning which serve our everyday human purposes. This problem is compounded still further when account is taken of the fact that this common-sense reasoning seems not to follow standard patterns at all, much less the deductive patterns captured by extensional first-order logic and by those of its close cousins exploited in the standard A.I. literature.[(15)]

The drive toward realistic ontology suffers most importantly however from the fact that A.I. naive physics is in its actual practice all too often willing to substitute more familiar artefacts of its chosen logical machinery for the treatment of common-sense concepts themselves in strict and realistic fashion. Thus Davis, for example, takes it for granted that the appropriate way to analyze ‘Calvin is in the living room’ lies via the shamefacedly counter-commonsensical set-theoretic translation into: ‘the set of spatial points making up the region occupied by Calvin is a subset of the set of points making up the living room’ (1990, p. 248). Similarly he suggests that in order to express an assertion pertaining to family relations for example: that Tom bears the same relation to Dick as Bruno bears to Fritz it is necessary to conceive such an assertion as amounting to an assertion to the effect that <Tom, Dick> and <Bruno, Fritz> are both members of a certain set of ordered pairs (1990, p. 8). Such translations are an artifice of logic; and they are as far removed from common-sense ontology as they are from the representation of common-sense reasoning as this exists in actual reality. It is out contention, further, that the use of set-theoretic machinery here is an example of a quite general tendency to reductionism in modern A.I. naive physics which runs counter to the very project of naive physics as a discipline which rests on the idea that it is possible to take certain macrophysical descriptions of the world *at face value.*

III. BRANCHES OF NAIVE PHYSICS

The task of naive physics, which is that of establishing an adequate theory of the structures and relations caputred in such descriptions, is for a variety of reasons not an easy one. Hayes, above all, has stressed the extent to which the concepts of naive physics are subject to a massive holistic interconnectedness in the sense that each is intervolved with all the others in ways which make it difficult, if not impossible, to distinguish distinct and separable branches of the discipline at hand. (Hayes 1979, 175ff) One should speak instead, he argues, of only loosely discriminable conceptual clusters, bearing in mind always that the concepts in each cluster are capable of being understood only by appeal to concepts in other, neighbouring clusters. One partial and provisional list of such sub-branches of the discipline might read as follows:

1. Objects, Natural Units and Natural Kinds

2. Events, Processes and Causality

3. Stuffs, States of Matter, Qualities

4. Surfaces, Limits, Boundaries, Media

5. Motivation, Requiredness, Value

The first four of these are standard (compare e.g. the list supplied by Hayes 1979, pp. 187-97). The fifth, however, which derives from phenomenology and from the Gestalt-theoretical perspective on naive-physical reality, is non-standard, in the sense that phenomena of value are not normally classed as belonging to 'physics' in either the naive or sophisticated senses.

In what follows we shall sketch a range of illustrative examples of early contributions to the field of naive physics. These early contributions are unaffected by the predominance of the desire to achieve ('quick and dirty') formal representations: they are contributions to the sophisticated and non-reductionistic theory of common sense, rather than contributions to the computerized representation thereof. On the other hand however these early contributions remain in many cases at the level of isolated insights and much of the work of combining them into a full and adequate theory has still to be done. In our remarks in what follows we shall proceed always in keeping with the spirit of a realistic ontology. Thus we shall take the world of common sense as serving at one and the same time as (1) an object of a sophisticated theory and also (2) as that to which we have ready access in straightforward and non-theoretical everyday experience. For as already Avenarius (in his fashion) saw, naive physics is part of an answer to the question: what do we (straightforwardly) perceive? What, then, are the branches of the theory of the world of straightforward perception?

1. Objects, Natural Units and Natural Kinds

The common-sense world is from the formal-ontological perspective first of all a world of things, of stable material bodies that are given to us *as* things in the sense that they are given as inert, as complete and as three-dimensional. Each thing is present in the flesh, as something which has surfaces and an inside, that is filled with matter. Things are perceived also as manipulable units, and as potential subjects of fragmentation (splitting, cutting) and of unification (gluing, bonding). The articulation of the world of things now follows along natural lines: objects inanimate as well as animate are grouped together according to their typical patterns of behaviour and qualitative determination into *natural kinds*. The common-sense world is further such that in all its spheres and dimensions we can distinguish what is 'normal' and what is to a greater or lesser degree 'abnormal'. Thus the natural kinds in commonsensical reality have both standard and non-standard instances. Both Gestaltists and phenomenologists have insisted from the start further on the *optimality* of perceived objects; even where the objects themselves are marked by various deviations from the norm, there is a tendency to discount such deviations in our straightforward experience of things and in our assignment of things to kinds or categories (a notion linked also to Mach's principle of the 'economy of thought', as also to the familiar phenomenon whereby even the scientific image of reality must in every case be rooted in the categories of common sense[(16)]).

There is normal and abnormal also among experiences and among the *conditions* of experience. Consider, for example, the ways in which colour-appearances differ under different lighting conditions. 'Normal', here, is

> seeing in sunlight, on a clear day, without the influence of other bodies which might affect the colour appearance. The 'optimum' which is thereby attained then counts as the *colour itself,* in opposition, for example, to the red light of the sunset which 'outshines' all proper colours. (Husserl 1952, p. 59)

In normal experience, then, we take ourselves as having access to the things themselves and to their real states. Other appearances are taken by common sense as secondary to or as deformations of that optimal appearance which alone counts as an appearance of reality. 'The features which pertain to the thing ''itself'' are the ''optimal'' ones. This applies to all features, to the geometrical as well as to the sensuous qualities.' (Husserl 1952, p. 76f.)

All families (kinds, species) of objects in the common-sense world are subject to the opposition between normal (standard, typical) and abnormal (non-standard, non-typical) instances.[(17)]

And the normal instances of such species are marked by familiarity, they are *understood* by common sense, both in regard to what they are and also in regard to what they will do (in regard to their regular patterns of behaviour in normal and regular circumstances). Thus I grasp a door, or a leaf, *in one stroke*, and I know already the sorts of future ways in which this thing will behave.

2. Events, Processes and Causality

The common-sense world of material entities is bicategorial: in spite of certain revisionary attempts on the part of Whitehead (1929), Kotarbinski (1955), Quine (1960, § 36), and others traces of which appear in Hayes' treatment of *histories* (1979, p. 189ff, 1985a) we still find it necessary to insist that common sense takes material objects and processes/events as belonging to two utterly different though interdependent categories.[(18)]

The work of the Polish phenomenologist Roman Ingarden (1935, 1964/65/74) includes what is probably the most detailed bicategorial ontology of things and processes/events to date, regarding processes as extended in time and events as boundaries (beginnings, endings or crossings) of processes. He thus stands opposed not only to monocategorial ontologies in the spirit of Kotarbinski or Quine but also to the Whiteheadian conception of processes as series of events. The Ingardenian classification can be supplemented by those which one finds in Thom (on confluences and convergences of processes, etc.[(19)]). Thus instantaneous events can be sub-divided into culminations (a sudden turn) and achievements (a victory). A widely exploited analogy (e.g. Bach 1986, Galton 1984) is that between instantaneous events and unitary things on the one hand and between processes and masses or stuffs on the other. Thus processes (of growth or disintegration) are like stuffs in that they can be divided into parts which are themselves processes.

Mention must be made in this connection also of the Gestaltists' work on process/event perception in the tradition of Gibson and G. Johansson. Thus Cutting (1981) sets out a number of conditions on event perception, which can also be taken as salient features of events themselves. An event or process if it is to be salient (to be discriminated as this or that event within a whole dynamic situation) must have an underlying invariant structure of properties that does not change (this might be the shape of the object involved, for example). These invariants concern both the whole event and also parts thereof, and they are hierarchically organized in the sense that some are essential, others inessential or such as to depend upon the former, essential properties. Each whole dynamic situation has one or more centre, for example the fulcrum of an acting lever, which are picked up and tracked in perception.[(20)]

The common-sense world is causally organized -- as was recognized for example by Husserl, whose account of the common-sense world put forward in his 1952 is built around the two central notions of *cause* and *change.* To know a thing, Husserl argues, is to know its causal dependencies: it is to know how it will change under given influences, how it will behave when heated or bent. But it is to know also in what respects it will remain the same through given series of changes, and it is part of our common-sense understanding of reality that its denizensa re such as to manifest a limited repertoire of systematic regularities in this respect, in the sense that under similar circumstances similar series of changes occur.

There are different sorts of change in the realm of common sense. Thus for example there is change that is *internal*, as e.g. when a person gets angrier of his own accord. Cases of this sort can be contrasted with changes caused by external circumstances, for example when a thing is dented or bruised. Changes can be divided further into changes in mere appearance (as when objects appear lighter through a change in external lighting conditions) and real changes (as when the apple ripens or a piece of metal expands).

Our bodies, too, of course are involved in causal dependencies, and yield the most important family of examples of real change, both internal and external. The body is a thing in space, with its form (extension) and its stock of qualities. The system of causalities into which my body is interwoven in normal experience is moreover such that my body retains *an identity of type and of function* through all its changes. Thus my limbs return again and again to the same basic positions. They can again and again accomplish the same sorts of things (lifting, turning, running) in the same sorts of regular ways. (Cf. Husserl 1952, pp. 61, 73)

Among the most important changes in the body, now, are those changes we call sensory perceptions. The network of sensory changes in the body is interwoven with other networks of changes, above all with changes of position and orientation, and more generally with the body's movements. Husserl in fact anticipates here the later position of J. J. Gibson (as also of Merleau-Ponty and others) concerning the necessary interwovenness of perception as a naturally occurring phenomenon with bodily movements on the part of the perceiving subject.[(21)]

3. Stuffs, States of Matter, Qualities

The world of experience is characterized by the fact that it has a qualitative aspect: its basic unities (things) are in such and such qualitative states and are filled through and through by sensory qualities. Not everything that we perceive is a thing. We perceive also the gaps between things,[(22)] holes,[(23)] the media (for example water, smoke) in which things move, and we can perceive holograms as well as rainbows and similar phenomena.

Things, now, are in common-sense experience spontaneously correlated with discriminable areas of organization within the continuum of what is given in sensory experience. Within this continuum centres are picked out, centres of accumulation of sensory qualities (where accumulation, here, is to be understood in the usual topological sense[(24)]). As Husserl pointed out, when we perceive a thing, then we perceive also sensuous qualities. But the latter are not there as it were *alongside* the physical thing; what is there before us is a unity, something which has physical and sensible properties as one. Moreover, the different strata of sensible properties are themselves bound intimately together: the things we experience are not built out of separate or separable seen, heard and touched constituents. Rather, there is but one thing, along with its properties, 'some of which are predominantly or exclusively (as, e.g., colours and their distinctions) grasped by vision, others by touch.' (Husserl 1952, p. 70)

The multidimensional sensory continuum with its various centres of accumulation is marked further by the feature of extension. Everything that belongs to a material thing is related as a matter of essence to its extension. Extension is, as it were, the axial determination of the thing. Whatever other determinations the thing has, both as a whole and in its parts, it has these determinations across the whole relevant extent they fill its corporeal space. (Cf. Husserl 1952, p. 30). Thus the coloration of an opaque thing covers the entire outer surface of the corporeal thing in its specific fashion. Warmth fills the warm body in another, quite different fashion, and matters are different again as concerns hardness, texture, weight, and so on.[(25)]

The complexity of the relationship between colour and extension was hinted at already by Hering (1905), who talks of colour as a sort of primitive stuff. Bits of this stuff, he holds, are colour expanses, three-dimensional entities which are made up of colour as such (an idea taken up again by Quine in his *Word and Object* (§ 19) via the thesis that colour terms are mass terms). In his 1911 David Katz puts forward a taxonomy of the modes of appearance of colour *in space* which are in fact modes of diffusion or filling of space by different sorts of sensible qualities. Thus for instance surface colour densely occupies a plane; it has texture and is diposed on planes of various intrinsic orientation; volume colour is lacking in texture; film colour is disposed on a plane that is always orthogonal to the line of sight of the viewer; and so on. The French perceptual psychologist Jean Nogué, generalizing Katz's results, went so far as to classify the ways in which different sensous qualities (colours, sounds, odours) fill space. If one interprets this classification from the point of view of space itself, one can claim that space is sensorily organized following different topologies. The typical mode of diffusion of odours given off by a source, for example, organizes the relevant space into non-oriented olfactory tracks; the recognition of a sound source, on the other hand, organizes the space of the auditor in oriented auditory paths; colours, in contrast, *enclose* or *envelope* space.[(26)]

A part of this programme is developed also by Husserl's doctoral student Wilhelm Schapp, who published in 1910 his *Contributions to the Phenomenology of Perception*, an attempt to defend a much extended variety of direct realism in the theory of perception. Visual perception, Schapp argues, gives us immediate access not only to things and their colour and form, but also to elasticity, solidity and other dispositional properties:

> We see whether a thing is smooth, as we see whether the brass of the lamp is rough like our suit or whether it is liquid like the water or the coffee or whether it is solid like the cup; whether it is homogeneous like the brass, or grainy like the table; whether it is sticky like the honey or runny like the ink. (1910, p. 19)

Schapp especially contrasts cases in which some parts only of an object are seen as moving with cases in which the whole of an object moves:
The case where the whole thing moves offers us little insight into the 'inner structure' of the thing. We then see for example only the lightness or the heaviness of the thing. (1910, p. 21)
When, on the contrary, some parts of the object move whereas others do not, and this in a way which follows some lawlike pattern, then we can see whether a body is elastic or whether it is composed of viscous or solid matter (p. 22f). The configuration that is manifested by a given qualitative filling of space both in dynamic cases, as in the perception of elasticity, and also in static ones, as in the perception of surface qualities such as lustre gives us access to certain structural properties of the perceived thing. And this kind of knowledge which is employed by the craftsman, for example Schapp contrasts explicitly with that of the natural scientist (pp. 19, 21-26).

What is most interesting about the structural properties picked out by Schapp is that they are properties relating to the *stuff* of things: to their solidity, fluidity, and the like. Hedwig Conrad-Martius, another early phenomenologist, offers complementary investigations of phenomena linked to stuffs in her *Realontologie* of 1924. What differentiates stuffs, according to Conrad-Martius, is their qualitative structure in space:

> Material being *is* substantial fulness in space. And it is precisely the manner in which this fulness is put together in space which leads to the range of different modalities of material constitution (§ 122).

In chapter 3 ("Concrete Forms of Stuff") Conrad-Martius then analyzes the ways in which sound and noise bear witness to the internal organization of stuffs. She also analyzes the qualitative features of temperature and light and offers a discussion of the different states of matter (§§ 135-70), of naive atomistic explanations (§ 162), of such dispositional properties of stuffs as elasticity, fragility and so on (§§ 171-80), and of aggregates (§ 176).

In this connection it is worth pointing out also that as early as 1902 Pierre Duhem traced the history of the scientific notion of 'mixture' and provided an outline of its common-sense background in certain elementary human operations. The concept of mixture, as he notes, serves to link conceptually the two notions of aggregate or assembly on the one hand and stuff in the strict sense on the other.

4. Surfaces, Limits, Boundaries, Media

A systematic ontology of surfaces has been put forward in Stroll's classic (1988), where he also investigates the role that is played by surfaces from the point of view of epistemology. Stroll contrasts two conceptions of surfaces: as *two-sided interfaces* (the surface of an apple would in this sense involve both thing and medium); and as *outermost layers* (where only the apple itself is involved).

Descriptive details of the theory of surfaces are to be found primarily in Gibson (1986), in the section entitled "Surface and the ecological laws of surfaces". As Gibson writes:

> According to classical physics, the universe consists of bodies in space. We are tempted to assume, therefore, that we live in a physical world consisting of bodies in space and that what we *perceive* consists of objects in space. But this is very dubious. The terrestrial environment is better described in terms of a *medium*, *substances*, and the *surfaces* that separate them. (1986, p. 16)

The medium, then, is separated from the substances of the environment by surfaces, each surface being such as to have a characteristic texture depending on the composition of the stuff of the relevant underlying substance.[(27)] Gibson seeks accordingly 'a theory of surface layout, a sort of applied geometry that is appropriate for the study of perception and behavior' and which would investigate concepts such as: ground, open environment, enclosure, detached object, attached object, hollow object, place, sheet, fissure, stick, fibre, dihedral, etc. (1986, p. 33)

Husserl, on the other hand, describes media as the normal environment for solid objects; they are *amorphous*, in the sense that they receive their form from the presence of material bodies in them.[(28)] Media are furthermore the vehicles of causality, and as a by-product of this they carry *information* about causal sources of all kinds. They are usually transparent in the sense that they do not themselves become objects of cognition in normal cases, though they can, in special circumstances, be properly representable in experience and they can be turned into such non-standard things as clouds of smoke, and so on.

Fritz Heider's "Thing and Medium" (1926), an elaboration of part of his doctoral dissertation written in Graz under Meinong's direction, seeks an answer to a question central to causal theories of perception: why, when we look at an object, do we perceive the object and not the illuminating source, when the latter is after all causally responsible for the perceptual experience?[29] Heider then analyzes the ambient conditions under which remote objects can be perceived. Not satisfied with the simple statement of a causal relation between the distal and proximal stimuli, he introduces concepts such as *relative dominance*, *order* and *disorder* to account for the unaffectedness of the medium in the course of the transfer of information. A solid thing, he holds, is normally unsuited for the transmission of information which requires a certain causal independence of the vehiculating parts involved. Heider's work then finds echoes in Gibson's notion of perception as a picking up of information in the ambient light (cf. esp. 1986, ch. 2).[30]

5. Motivation, Requiredness, Value

The world of common sense in contrast to the naive-*physical* worlds described by Hayes, *et al*. is both salient and valuable: it is shot through with complex gradients of *preferability*. The relevance of this fact to a treatment of naive physics, now, turns on the fact that one central aim of naive-physical investigations is to find a means of simulating human action by means of intelligent artifacts. For it seems clear that our human capacity successfully to find our way around the physical world depends crucially upon the spontaneous ways in which we take such value-differentials into account.

Our perceptual experiences are *caused* by objects and they are grasped as such from the perspective of common sense. Experiences are thereby bound together dynamically with the objects of this world through relations of causality. Experiences and the objects of the common-sense world are also bound together dynamically in a second sense, however, in that the objects of this world, on being experienced, exert positive and negative forces upon me belonging not to the sphere of causality but to that of human salience and value. The common-sense world is in this sense a meaningful dynamic whole that is shaped in manifold ways by forces of attraction and repulsion.

One is reminded in this connection of the Gestalt-theoretical notion of 'requiredness' introduced by Köhler. Requiredness is a form of reference, it is a relation *from* one thing *to* another. Requiredness differs from other forms of reference, however, by its *demanding* character. 'It involves acceptance or rejection of the present status of the context in question, often more particularly, acceptance or rejection of some part by the remainder of the context.' (1938, p. 336)

When I apprehend things and persons and surrounding circumstances I am determined by what Husserl calls 'motivations'. One object steers my regard onto itself through its special form. Another draws attention to itself through its beautiful colour or texture. The noise out there makes me close the window. The glass of beer over here makes me reach out my arm to grasp it:

> In short, in my theoretical, emotional, and practical behaviour in my theoretical experience and thinking, in my position-taking as to pleasure, enjoyment, hoping, wishing, desiring, wanting *I feel myself conditioned by the matter in question* (Husserl 1952, p. 140, cf. also p. 219).

It is an invariant feature of our straightforward experience that the objects motivate us in this sense. There are 'effects' on the subject emanating from the objects, effects of greater or lesser intensity. And then, as Köhler points out: 'The lower this intensity, the more will a condition of merely factual [i.e. physical] relation, juxtaposition, or sequence be realized.' (1938, p. 337)

We can consider as a thought experiment the idea that we might present to ourselves the objects of the common-sense world *merely* perceptually. As subjects of this world, however, we are not merely perceiving but also *acting* beings, and thus constantly subject to corresponding motivations. Thus in normal conditions we effect spontaneous evaluations of the objects by which we are confronted in a way which amounts to a sort of *value-perception*: 'the value-character itself is given in original intuition.' (Husserl 1952, p. 186) We directly experience the world as containing values, and thereby also we acquire mediate and immediate goals: objects 'afford' action, in Gibson's phrase. These affordances give rise in turn to new motivational connections in light of the interrelations between the various different goals and sub-goals in whose realization we are at any given moment engaged. These values and goals can then be seen as a new dimension of being within the common-sense world itself, a dimension which, we should argue, is crucial to our capacity to find our way around this world in a physical sense.

Conclusion

As most workers in the field of artificial intelligence have recognized, naive physics is far from being a single, unified discipline. Clusters and sub-clusters of concepts are investigated in a piecemeal way, without much concern for their relation to the whole, in spite of the fact that, as we stressed earlier, this conceptual network is marked by strong holistic features which are reinforced by the pervasiveness of spatial concepts and by the focus on those interactions which are relevant to the concerns of our everyday human behaviour.

We have also seen that contemporary representations of common-sense experience in the sphere of naive physics are over-narrow to a degree which has had dramatic consequences for their reliability as representations. We suggested earlier that this narrowness depends on too quick a jump to implementationally attractive features of certain special means of representing naive-physical knowledge, means derived, in effect from the fundamentally atomistic (non-holistic) world of set theory. Against this tendency we wish to stress once more the need for a wider, and deeper, and more painstaking *phenomenological* investigation of the naive-physical realm and of the associated value-laden dimensions of the world of common-sense experience. The work of the Gestalists and of Gibson, taken together with work in naive physics and in formal ontology in the tradition of the early phenomenologists, has the chance of providing a unifying *theoretical* framework for the development of a realistic account of the structures here involved, in ways which can, we suggest, be of value also in the construction of more adequate theories of the sort that are still needed by naive physicists in the field of artificial intelligence.

References

Bach, E. 1986 “The Algebra of Events”, *Linguistics and Philosophy*, 9, 5-16.

Becker, Oskar 1923 “Beiträge zur phänomenologischen Begründung der Geometrie und ihrer physikalischen Anwendungen”, *Jahrbuch für Philosophie und phänomenologische Forschung*, 6, 385-560.

Boden, Margaret A. (ed.) 1990 *The Philosophy of Artificial Intelligence*, Oxford: Oxford University Press.

Bozzi, P. 1958 “Analisi fenomenologica del moto pendolare armonico”, *Rivista di Psicologia*, 52, 281-302.

Bozzi, P. 1959 “Le condizioni del movimento ‘naturale’ lungo i piani inclinati”, *Rivista di Psicologia*, 53, 337-352.

Bozzi, P. 1961 “Fenomenologia del movimento e dinamica pregalileiana”, *Aut Aut*, 64, 1-24 and 377-93.

Bozzi, P. 1989 “Sulla preistoria della fisica ingenua”, *Sistemi intelligenti*, 1, 61-74.

Bozzi, P. 1991 *Fisica ingenua*, Milan: Garzanti.

Carnap, Rudolf 1922 *Der Raum. Ein Beitrag zur Wissenschaftslehre* (*Kant-Studien*, Ergänzungsheft 56), Berlin: Reuther & Reichard.

Casati, R. and Varzi, A. 1992 *Holes and Other Superficialities*, Research Group on the Philosophy of Perception, Geneva.

Clement, John 1982 “Students’ Preconceptions in Introductory Mechanics”, *American Journal of Physics*, 50, 66-71.

Conrad-Martius, Hedwig 1923 “Realontologie”, *Jahrbuch für Philosophie und phänomenologische Forschung*, 6, 159-333.

Cutting, J. E. 1981 “Six Tenets for Event Perception”, *Cognition*, 10, 71-8.

Davis, Ernest 1990 *Representations of Commonsense Knowledge*, San Mateo, California: Morgan Kaufmann Publishers, Inc.

DiSessa, A. A. 1982 “Unlearning Aristotelian Physics: A Study of Knowledge-Based Learning”, *Cognitive Science*, 6, 37-75.

DiSessa, A. A. 1985 “Learning about Knowing”, *New Directions for Child Development*, 28, 97-124.

Duhem, Pierre 1902 *Le mixte et la combinaison chimique*, Paris: C. Noud.

Feyerabend, Paul 1978 “In Defence of Aristotle: Comments on the Condition of Content Increase”, in G. Radnitzky and G. Andersson, eds., *Progress and Rationality*, Dordrecht: Reidel, 143-180.

Fieandt, K. van 1949 “Das phänomenologische Problem von Licht und Schatten”, *Acta Psychologica*, 6, 337-57.

Forbus, K. 1984 “Qualitative Process Theory”, *Artificial Intelligence*, 24, 85-168.

Friescheisen-Köhler, Ide 1933 *Das persönliche Tempo*, Leipzig.

Galton, Antony 1984 *The Logic of Aspect. An Axiomatic Approach,* Oxford: Clarendon Press.

Garfield, Jay L. 1988 *Belief in Psychology. A Study in the Ontology of Mind*, Cambridge, Mass.: The MIT Press.

Gibson, J. J. 1966 *The Senses Considered as Perceptual Systems,* London: George Allen and Unwin.

Gibson, J. J. 1986 *The Ecological Approach to Visual Perception*, Boston: Hillsdale: Lawrence Erlbaum.

Hager, Greg 1985 “Naive Physics of Materials: A Recon Mission”, in *Commonsense Summer: Final Report*, Report No. CSLI-85-35, Center for the Study of Language and Information, Stanford University, Stanford, California.

Hayes, Patrick, J. 1979 “The Naive Physics Manifest”, in D. Michie, ed., *Expert Systems in the Micro-Electronic Age*, Edinburgh: Edinburgh University Press, 242-70, as repr. in Boden, ed., 171-205.

Hayes, Patrick J. 1985 “The Second Naive Physics Manifesto”, in Hobbs and Moore, eds., 1-36.

Hayes, Patrick J. 1985a “Naive Physics I: Ontology for Liquids”, in Hobbs and Moore, eds., 71-107.

Heider, Fritz 1926 “Ding und Medium”, *Symposion*, 1, 109-57, Eng. trans. (slightly shortened) in Heider 1959, 1-34.

Heider, Fritz 1983 *The Life of a Psychologist*, Kansas University Press.

Hering, E. 1905 *Grundzüge zur Lehre vom Lichtsinne*, Berlin: Spring. Eng. trans. *Outlines of a Theory of the Light Sense*, Harvard: Harvard University Press, 1964.

Hobbs, J. R. and Moore, R. C. eds. 1985 *Formal Theories of the Common-sense World*, Norwood: Ablex.

Husserl, E. 1952 *Ideen zu einer reinen Phänomenologie und phänomenologischen Philosophie*, Second Book: *Phänomenologische Untersuchungen zur Konstitution*, The Hague: Martinus Nijhoff, trans. as *Ideas*, Second Book, Dordrecht: Kluwer Academic Publishers, 1989.

Husserl, E. 1970 *The Crisis of European Sciencesand Transcendental Phenomenology. An Introduction to Phenomenological Philosophy*, trans. by D. Carr, Evanston: Northwestern University Press.

Husserl, E. 1973 *Ding und Raum. Vorlesungen 1907*, ed. by U. Claesges, The Hague: Nijhoff.

Ingarden, R. 1935 “Vom formalen Aufbau des individuellen Gegenstandes”, *Studia Philosophica*, 1, 29-106.

Ingarden, R. 1964/65/74 *Der Streit um die Existenz der Welt*, Tübingen: Niemyer, 3 vols.

Jaeger, Siegfried (ed.), 1988 *Briefe von Wolfgang Köhler an Hans Geitel 1907-1920* (Passau Schriften zur Psychologiegeschichte, 9), Passau: Passavia Universitätsverlag.

Johansson, Gunnar 1950 *Configurations in Event Perception. An Experimental Study*, Uppsala: Almqvist and Wiksell.

Kaila, Eino 1936 “Über das System der Wirklichkeitsbegriffe. Ein Beitrag zum logischen Empirismus”, *Acta Philosophica Fennica*, 2, Eng. trans. in Kaila, *Reality and Experience. Four Philosophical Essays*, Dordrecht/Boston/London: Reidel, 1979.

Kanizsa, Gaetano 1979 *Organization in Vision. Essays on Gestalt Perception*, New York: Praeger.

Katz, D. 1911 *Die Erscheinungsweisen der Farben*, *Zeitschrift für Psychologie*, Ergänzungsband, modified trans. as *The World of Colour*, London: Kegan Paul, Trench and Trubner, 1935.

Keesing, R. M. 1987 "Models, 'Folk' and 'Cultural'", in D. Holland and N. Quinn, eds., *Cultural Models in Language and Thought*, Cambridge; Cambridge University Press, 369-393.

Keiler, P. 1980 "Isomorphie-Konzept und Wertheimer-Problem: Beiträge zu einer historisch-methodologischen Analyse des Köhlerschen Gestaltansatzes. I. Erkenntnistheoretische und seinslogische Implikationen des Isomorphie-Konzepts", *Gestalt Theory,* 2, 78-112.

Kirschmann, A. 1895 "Der Metallglanz und die Parallaxe des indirekten Sehens", *Philosophische Studien*, 9, 147-87.

Köhler, Wolfgang 1921 "Intelligenzprüfungen an Anthropoiden", *Abhandlungen der Preussischen Akademie der Wissenschaften. Jahrgang 1917, Physikal.-Mathem. Klasse*, 1; Eng. trans. of 2nd German ed. as *The Mentality of Apes*, London: Kegan Paul, Trench, Trübner, 1927.

Köhler, Wolfgang 1938 *The Place of Value in a World of Facts,* New York: Liveright.

Köhler, Wolfgang 1947 *Gestalt Psychology*, New York: Liveright.

Kotarbinski, T. 1955 "The Fundamental Ideas of Pansomatism", *Mind*, 64, 488-500.

Lipmann, Otto and Bogen, Hellmuth 1923 *Naive Physik. Arbeiten aus dem Institut für angewandte Psychologie in Berlin. Theoretische und experimentelle Untersuchungen über die Fähigkeit zu intelligentem Handeln*. Leipzig: Johann Ambrosius Barth.

McCloskey, M. 1983 "Naive Theories of Motion", in Gentner and Stevens, eds., 299-324.

McCloskey, M. 1983a "Intuitive Physics", *Scientific American*, 248(4), 122-130.

McDermott, Drew 1990 "A Critique of Pure Reason", in Boden, ed., 206-230.

Meinong, A. von 1906 *Über die Erfahrungsgrundlagen unseres Wissens*, Berlin: Springer, repr. in Meinong, *Gesamtausgabe*, vol. V, ed. by R. M. Chisholm, Graz: Akademische Druck- und Verlagsanstalt, 1973.

Menger, K. 1940 “Topology without Points” , *Rice Institute Pamphlets*, 27, 80-107.

Metelli, F. 1974 “The Perception of Transparency”, *Scientific American*, 230, 90-98.

Michotte, Albert 1963 *The Perception of Causality*, London: Methuen, 1963.

Musatti, C. 1926 *Analisi del concetto di realtà empirica*, Città di Castello: Il Solco, repr. in C. Musatti, *Condizioni dell’esperienza e fondazione della psicologia*, Florence: Editrice Universitaria, 1964, 13-175.

Nicod, Jean 1924 *La géometrie dans le monde sensible*, Paris: , Eng. trans. in Jean Nicod, *Geometry and Induction*, London: Routledge and Kegan Paul, 1970.

Nogué, J. 1936 *La signification de sensible*, Paris: Aubier.

Peters, P. C. 1982 “Even Honors Students have Conceptual Difficulties with Physics”, *American Journal of Physics*, 50, 501-508.

Petitot, J. 1989 “Morphodynamics and the Categorial Perception of Phonological Units”, *Theoretical Linguistics*, 15, 25-71.

Petitot, J. 1989a “Hypothése localiste, Modèles morphodynamiques et Théories cognitives”, *Semiotica*, 77, 65-119.

Petitot, J. 1990 “Le Physique, le Morphologique, le Symbolique. Remarques sur la Vision”, *Revue de Synthése*, 4, 139-183.

Petitot, J. and Smith, B. 1990 “New Foundations for Qualitative Physics”, J. E. Tiles, G. T. McKee and C. G. Dean, eds., *Evolving Knowledge in Natural Science and Artificial Intelligence*, London: Pitman Publishing, 231-249.

Piaget, Jean 1945 *La formation du symbole chez l’enfant*, Neuchâtel and Paris: Delachaux et Niestlé.

Piaget, Jean 1946 *Les notions de mouvement et de vitesse chez l’enfant*, Paris: PUF.

Pittenger, J. B. and Runeson, S. 1990 “Paolo Bozzi’s Studies of Event-Perception”, *ISEP [International Society for Event Perception]*, IV.

Quine, W. V. O. 1960 *Word and Object*, Cambridge, Mass.: The MIT Press.

Rosch, E., Mervis, C.B., Gray, W., Johnson, D. and Bayes-Braem, P. 1976 “Basic Objects in Natural Categories”, *Cognitive Psychology*, 8, 382-439.

Runeson, S. 1974 “Constant velocity - non perceived as such”, *Psychological Research*, 37, pp.

Russell, Bertrand 1948 *Human Knowledge. Its Scope and Limits*, London: George Allen and Unwin.

Schapp, W. 1910 *Beiträge zur Phänomenologie der Wahrnehmung*, Göttingen: Kaestner.

Schutz, A. 1959 “Type and Eidos in Husserl’s Late Philosophy”, repr. in A. Schutz, *Collected Papers,* vol. III, *Studies in Phenomenological Philosophy,* The Hague: Nijhoff, 1975, 92-115.

Scanlon, John 1988 “Husserl’s *Ideas* and the Natural Concept of the World”, in R. Sokolowski, ed., *Edmund Husserl and the Phenomenological Tradition*, Washington, D.C.: The Catholic University of America Press, 217-233.

Sellars, W. F. 1963 “Philosophy and the Scientific Image of Man”, ch. 1 of *Science, Perception and Reality,* London: Routledge and Kegan Paul.

Simons, P. M. 1987 *Parts. A Study in Ontology*, Oxford: Clarendon Press.

Smith, B. 1986 “The Theory of Value of Christian von Ehrenfels”, in R. Fabian (ed.), *Christian von Ehrenfels: Leben und Werk,* Amsterdam: Rodopi, 150-71.

Smith, B. 1988 “Gestalt Theory: An Essay in Philosophy”, in in Smith, B. ed., 11-81.

Smith, B. 1990 “On the Phases of Reism”, in J. Woleski, ed., *Kotarbiski: Logic, Semantics and Ontology*, Dordrecht/Boston/London: Kluwer, 137-184.

Smith, B. 1991 “Characteristica Universalis”, in K. Mulligan, ed., *Language, Truth and Ontology* (Philosophical Studies Series), Dordrecht/Boston/London: Kluwer, 50-81.

Smith, B. 1994] “The Structures of the Commonsense World”, in A. Pagnini and S. Poggi, ed., *Gestalt Psychology. Its Origins, Foundations and Influence,* Florence: Olschky, 1992.

Smith, B. ed. 1982 *Parts and Moments. Studies in Logic and Formal Ontology*, Munich: Philosophia.

Smith, B. ed. 1988 *Foundations of Gestalt Theory*, Munich/Vienna: Philosophia.

Stroll, A. 1988 *Surfaces*, Minneapolis: University of Minnesota Press.

Talmy, Leonard 1983 "How Language Structures Space", in H. Pick and L. Acredolo, eds., *Spatial Orientation: Theory, Research, and Application*, New York: Plenum Press.

Thom, René 1988 *Esquisse d'une sémiophysique*, Paris: Interéditions, Eng. trans. by V. Meyer, as *Semio Physics: A Sketch. Aristotelian Physics and Catastrophe Theory*, Redwood City, etc.: Addison-Wesley, 1990.

Weld, D. and Kleer, J. de, eds. 1989 *Readings in Qualitative Reasoning about Physical Systems*, Los Altos: Morgan Kaufmann.

Whitehead, Alfred North 1906 "On Mathematical Concepts of the Material World", *Philosophical Transactions of the Royal Society of London*, series A, V. 205, 465-525.

Whitehead, Alfred North 1929 *Process and Reality. An Essay in Cosmology*, New York: The Macmillan Company.

Witschel, Günter 1961 *Edmund Husserls Lehre von den sekundären Qualitäten*

Endnotes

1. The present paper has been prepared as part of a project on the "Formal-Ontological Foundations of Artificial Intelligence Research" under the auspices of the Swiss National Foundation.

2. See the papers collected together in Hobbs and Moore, eds. 1985 and in Weld and de Kleer, eds. 1989, as well as Davis 1990, Hager 1985 and Forbus 1984.

3. On direct influences see Keiler 1980; on indirect influences (above all via Ehrenfels) see Smith 1988.

4. Cf. Jaeger, ed. 1988, p. 156.

5. See e.g. Clement 1982, DiSessa 1982, McCloskey 1983, 1983a, Peters 1982 and the work of Bozzi discussed below.
Though hidden in a host of experimental reports, a conception close to that of naive physics is present also in the work of Jean Piaget, who investigated the 'construction' of different strata of reality in the child. (Of interest here are his investigations of causality, reality, number, quantities, relations, time and movement.) See Piaget 1946, p. vii, for an explicit reference to Aristotelian conceptions, and also 1945, ch. ix.

6. Gibson 1966, p. 21, 1986, p. xiii.

7. Gibson 1986, pp. xiii, 34f.

8. See e.g. Cesare Musatti, *The Analysis of the Concept of Empirical Reality*, 1926, and Gaetano Kanizsa, *Organization in Vision*, 1979.

9. Bozzi 1991, pp. 259ff, 285ff.

10. These same conceptions inspired also Bozzi's subsequent experimental work on the movement of bodies sliding down inclined planes (cf. Runeson 1974, Pittenger and Runeson 1990).

11. Cf. Simons 1987.

12. Cf. e.g. his "System of the Concepts of Reality", 1936.

13. See Smith, ed. 1982.

14. See the works of Petitot and of Petitot and Smith listed above.

15. On this issue see McDermott 1990.

16. Compare Sellars' discussion of the 'manifest image' of common sense: the scientific image, as Sellars points out, 'cannot replace the manifest image without rejecting its own foundations' (1963, p. 21), Moreover, the ability of our rarefied concepts of, say, elementary particles, to explain, and to induce understanding, 'derives from their origin in, and their gradual refinement from, the mundane concepts of the manifest image.' (Garfield 1988, p. 116) The physicist must of necessity appeal to the objects and processes of the common-sense world also when testing his theoretical constructions against experience.

17. Cf. the work of E. Rosch and her associates on the role of prototypes in perception and learning, and compare also the relevant work of Gestalt psychologists on the notion of '*Prägnanz*', work that is summarized by G. Kanizsa in his paper in this volume. See also the discussion of typicality in A. Schutz 1959.

18. Kotarbinski's 'pansomatism' is a monocategorial ontology which sees the world as made up entirely of (inert, three-dimensional) things; Whitehead, in contrast, defends a monocategorial ontology of processes. Quine, finally, defends a neutral monocategorialism which allows of no distinction between processes and things. See Smith 1990.

19. See Thom 1988 and the brief summary of Thom's views on event-types in Smith 1988, p. 34ff.

20. See Cutting 1981, p. 75. A structural typology along these lines was incidentally presented also by Bertrand Russell in his *Human Knowledge*; see his 1948, ch. ix, especially the discussion of what calls the ‘postulate of quasi-permanence’ and the ‘structural postulate’; cf. also the reference to Russell in Heider 1983, p. 39.

21. As Husserl puts it:

> *if* the eye turns in a certain way, *then* so does the ‘image’; if it turns differently in some definite fashion, then so does the image alter differently, in correspondence. We constantly find here this two-fold articulation . . . Perception is without exception a *unitary accomplishment* which arises essentially out of the playing together of two *correlatively related functions.* (Husserl 1952, p. 58. Cf. Gibson 1986, xiii)

22. See Husserl 1973, Beilage VII.

23. See Casati and Varzi 1992.

24. See Petitot and Smith 1990, which develops ideas by René Thom on the topology of the common-sense world.

25. Cf. G. Witschel 1961 for a summary of Husserl’s ideas in this direction, and also Katz 1911.

26. See Nogué 1936, p. 141 *et passim*. Interestingly parallel phenomena have been investigated by Talmy, e.g. in his 1983.

27. It is in his account of the structures of surfaces, now, that Gibson, in his advocacy of ecology, comes closest to Gestalt concepts. See e.g. 1986, p. 28, and compare also Kirschmann 1895 on sheen and van Fieandt 1949 on lustre.

28. See Book II of his *Ideas* (1952, Addendum to § 16).

29. This question is raised by Meinong in his 1906, § 25.

30. Cf. also F. Metelli’s work (1974) on the conditions under which we perceive various kinds of transparent and semi-transparent items.