COMMITTEE I
Unifying Principles in Science

DRAFT - 9/15/86
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THE CONSCIOUS ORGANISM IN SPACE AND TIME

by

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The Fifteenth International Conference on the Unity of the Sciences
Washington, D.C. November 27-30, 1986

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1. The Living Organism as a Physical Object.

Our world is a world of perpetual change. It is part of a dynamic universe and shares the basic characteristics of the latter. Any description of its material constituents must take the dynamic aspects into consideration. This means a description in terms of the categories of space and time or, within the framework of relativistic theory, of four-dimensional space-time. Further details are given in the paper by Dr. Jammer.

Dealing with living organisms, one meets at least three ways in which they are related to space and time:

1. Organisms and living systems follow the same basic laws of physics as inanimate matter.
2. Organisms additionally show a specific life history of their own: the ontogenetic development.
3. Organisms somehow make use of an internal representation of space and time in order to cope successfully with their environment. The details of this phenomenon and the neurophysiological mechanisms behind it are dealt with in the paper by Dr. Delgado.

Classical Newtonian physics uses the concepts of absolute space and time, but makes also a distinction between mathematical (absolute) and apparent or common space and time. (Newton, 1687, 1729). Newton here points out two things:

1. The conceptions of space, time, motion and location are supposed to be intuitively known.
2. One must make a distinction between the mathematical abstractions of absolute space and time and the common sense descriptions of relative space (location)

and time (duration), which are bound to observable movement and location of bodies.

Nevertheless, both appeal in an intuitive way to everyday experience, which later on might have contributed to the resistence against Einstein's Theory of Relativity (cp. Einstein, 1931). It may be of interest to note that the basic results of Einstein's theory were still debated during the sixties. An account and analysis of this controversy is given by Prokhovnik (1967).

From the point of view of evolutionary epistemology this might be expected, since the brain and nervous system are phylogenetically adapted to the mesocosmos of our natural environment from which they have eveolved. Mesocosmos here denotes the world of moderate distances, masses, velocities and energies (cp. Vollmer, 1986). This is in accordance with Newton's conception. As Riedl (1986) has pointed out, Einstein's great achievement to a large extent is based on his ability to overcome the natural limitations of habitual mesocosmic thought and thus to create the highly abstract conception of physical space-time.

It should be pointed out here that one must make a distinction between two ways in which the notions of "space" and "time" are used.

A) Space and time are attributes of the external physical world, which is supposed to exist independent of a living observer.

B) The biologically determined internal representation of space and time as categories of experience. The innate ability to "map" salient features of external reality is the result of the process of phylogenetic evolution. But this means that (B) somehow is a reflection of (A).

Throughout this paper both notions are used.

At least in human beings one may recognize three levels of "knowledge" (in the sense of "insight into" or "understanding"; the German "Erkenntnis" is most appropriate).

1. Pereptual knowledge, which is predetermined by the working principles of perceptual mechanisms. This knowledge is immediately available, non-revisable, uncritical, but instead perspicuous.
2. Knowledge by experience involves language, logic and a certain amount of abstract resoning.
3. Scientific knowledge , finally, is the result of critical thinking; its concepts are mostly highly abstract and often no longer perspicuous (Vollmer, 1982). The mathematical concepts of space and time were created at this level, which is only available to the human species.

It should finally be emphasized that notions such as space, time, motion and change are not only unifying concepts in that they apply to any description of physical objects and their history of existence, but also that change and evolution furthermore are essential characteristics of all living organisms.

2. The World Line of an Organism

The history of an object, whether stationary or moving in space, can be depicted in four-dimensional space-time (Minkowski world) as a curve which is called the world line of the object. The simplest case, the world line of a stationary point-like object, is a straight line. The world lines of living organisms are extremely complex, since the organism not only moves, but also changes its shape as a function of time. Such world line need not, of course, be thought of as a line, but rather as a massive, "tube-like" structure, which changes its shape, bends, expands and contracts. The 3-D nature of material objects would nevertheless demand a forth dimension in order to depict a naturalistic world line. An approximation would be to depict a large number of sequences from a motion picture simultaneously within a transparent medium, where one space dimension represents the dimension of time. The world line reflects, hence, also the life history of an organism,

its ontogenetic development from a fertilized egg (zygote) to its final death. This process has the character of a species-bound evolution, the determinants of which are phylogenetically á posteriori, but ontogenetically á priori. Ontogenesis was the only kind of evolution known to Aristotle, while the different species were thought to be a part of the divine act of creation.

Evolution, (originally latin = unrolling, uncoiling itself, unwrapping something) means today the consecutive coming into existence of new features.

Ontogenetic development, hence, reflects several aspects of life:

* life as a process
* life as a state of a living system (as opposed to the dead state)
* life as defining the time-span of the organism's existence between "birth" (or conception) and "death".

The average time-span of living organisms, if compared, ranges from hours for certain microorganisms to several thousand years for Sequoia-trees. In another sense, however, unicellular microorganisms (such as procaryotes) have an indefinite life span. These features are essentially genetically determined through a regulation of the metabolic rate and control of cell division. There exists a number of species-bound characteristics of phylogenetic development. No really clear correlations, however, exist between them.Such characteristics are:

* The reproductive cycle, i.e. the average length of a generation.
* The average life-span.
* The length of the prenatal (fetal) stage from conception to birth.
* The relative lenth of the postnatal preadult stage (which for the white albino rat comprises 8-10 % of its life time, for humans about 25 % of their life time).
* The relative complexity of the brain and the ratio between brain mass and total body mass. This ratio varies largely between species:

about 1: 70,000 for large dinosaurs,	about 1: 10,000 for some whales,
about 1: 500 for elephants,	about 1: 440 for fowls,
about 1: 250 for dogs,	about 1:80 for chimpanzees,
about 1: 50 for dolphins	about 1:50 for man.

(Berry, 1939; Munn, 1959).

* There exist physical factors which limit the final volume and mass of an organism. The volume increases with the third power of its linear size while the surface increases with the second power. The mass determines the amount of metabolized matter, the energy demand and the heat production, while heat exchange and evaporation are dependent on the available surface.

Gravitational pull determines the necessary bone structure and muscular strength. The limiting values differ, however, for terrestrial and sea animals. Suppose, that the giants of Brobdignag, which Gulliver met at his voyage, were 10 times his own height. Proportions alike, this would mean a 1000 times larger mass, approximately 70 tons and a tenfold larger load which the giants feet had to carry. Since the average sound frequency which is produced by an elastic membrane, e.g. by the vocal cords, is inversely proportional to its area, the giants would produce sounds in the range of nearly imperceptible low frequencies.[1)]

The life span of an organism correlates with its biological time scale, i.e. the duration of different ontogenetic stages in terms of conventional time units such as hours or days. It also relates to the reproductive rate and thus the rate of genetic variation by recombination of genes. This gives rise to a corresponding variation of phenotypes and the rate at which new ones emerge.

Since all living organisms feed on others or are dependent on them, the species bound time scale is an integrative factor within the delicately balanced ecological system on earth.

The early ontogenetic development is determined by two processes: cell divi-

sion and cell differentiation. All cell nuclei contain the same genetic information, i.e. identical sets of genes. Cell division must, hence, be preceded by a flawless duplication of the genetic set-up. It is well known that the genetic information is encoded in large strands of DNA-molecules in terms of nucleotides. This implies in principle that a spatial order of molecules determines the time order in which different parts of the ontogenetic process are performed. The details of these processes are tremendously complex. Some of these complexities have been nicely illustraded by Pincheira (1985). While ontogenesis in large is an irreversible process, it contains cyclically appearing subprocesses in the duplication of DNA and cell division.

Cell differentiation means a branching in the execution of genetic instructions. The mechanisms behind the phenomenon have puzzled scientists for a long time. There are several mechanisms which might contribute to cell differentation. Generally they imply a complex interaction between DNA and its cytoplasmatic environment. One factor is of topological nature in that the outermost layers of the growing cell assembly border a different biochemical environment.

A second factor which had been proposed earlier, is the emergence of so-called organizers (inductors), which induce the branching of chemical processes that lead to a differentiation of the cell (Waddington, 1955). It is one main task of genes to direct the synthesis of different proteins. Some of them interact later on with DNA. Certain segments of the DNA molecule, called operons, are controlled by nearby situated operatorgenes which can occupy two states: open and closed. During the open states the corresponding operons are active. Each operator is engaged by a specific cytoplasmatic repressor which itself is a product of a regulatorgene. The concentration of certain metabolites in the cytoplasma work as effectors which control the repressor (Stent, 1964).

Waddington (1957) describes ontogenetic development in terms of a metaphor. A

ball moves down a sloping "epigenetic landscape". Its topography represents the developmental pathway, its surface the genotype of the organism and the position of the ball represents the actual phenotype. This metaphor illustrates a multivariate functional relationship, where both the organism and its environment are dependent variables and ontogenetic time is the independent variable. Tha pathway of the ball is relatively stable to perturbations and is called a chrehod (greek = necessary path). It reflects a rather stable relationship between genotype and phenotype.

Ontogenetic development links the time dimension of a process to the shaping of the organism in space. Its description includes both the nature of different changes as well as the mechanisms which are responsible for their occurrence. One factor which influences the shape is symmetry or asymmetry.

Asymmetry is a more or less common feature of most multicellular organisms at different organizational levels. While some asymmetry is the result of ontogenetic processes (as well as symmetry in other cases), there exists a basic asymmetry at the molecular level in proteins (cp. e.g. Karlson, 1962) and aminoacids.

Examples of asymmetry at the macrolevel are the lateralization of single organs such as the heart, the slight asymmetry of the left and right half of the face, the asymmetry of the ears (the auricles are directed slightly forward), or the functional specialization (lateralization) of certain brain functions, although the brain always works as an integrated whole (see Ornstein, 1977; Gazzaniga & LeDoux, 1978).

Ontogenetic development means the gradual emergence of both somatic and behavioural phenotype properties. All members of the same species pass the same sequence of stages in the same chronological order, although the exact duration of each stage varies between individuals. Morphologically one finds (1) a differentiation of somatic structures, (2) an overall growth and (3) a change of body pro-

portions due to a differentiated rate of growth for the head, the body and the extremities. This development follows the cephalo-caudal (head to tail) and the proximo-distal principles. In human infants one can recognize the same order as to the sequence in which the intentional control of striate muscles is developed.

The direction of (ontogenetic) time is indicated somewhat differently during different phases of life:

1. The emergence of consecutive states with increasing complexity and information content during the period of growth.
2. An equilibrium state of cell renewal and cell decay during the adult stage.
3. A slow decrease of the renewal rate, the process of biological aging.

The most salient feature of higher animals, particularly human beings, is the development of a behavioural repertoire, comprising a mixture of qualitative and quantitative characteristics. The details could not be dealt with here. With respect to ontogenetic time, one roughly finds the order:

Reflexes → instinctive behaviour (genetically determined) → simple (basic) skills → complex skills → creative skills.

The order reflects an increase of complexity and a growing dependence on learning and intentional control. Skills are always the result of maturation (genetically controlled development of underlying mechanisms) <u>and</u> training (goal directed, systematic learning). Training, however, stimulates the process of maturation by means of feedback. General skills develop prior to special ones, simple skills prior to complex ones. The development of complex skills demands the establishment of automatically working basic skills. Creative skills demand well established complex skills (essentially what we call craftmanship).

A characteristic property of an individual is his or her personality. The concept of personality is intuitively well known, but it is difficult to define strict-

ly. It contains both genetically determined modes of reaction such as temperament, properties such as efficiency and capacity (related to intelligence) and acquired programs which relate to specific behaviour, aptitudes and knowledge.

The brain is to a high extent self-programming. It is an instrument for learning and information processing. We do not only learn intentionally during lessons or reading, but in all situations of everyday life.

The millions of events, which are constituents of an individual's world line are thus internalized and contribute towards shaping the unique pattern of this individual's personality. It is evident that the life history of an individual has aspects which not directly manifest themselves in terms of the world line, but which nevertheless profoundly influence its course.

3. The Animal in Space and Time.

All organisms somehow reflect the properties of the physical environment in which they have evolved. The distinction between humans and other animals is here mainly made on account of the available sources of information, since only human beings can communicate their experiences with the aid of language.

To protozoa, the lowest level of organism, which is of interest here, space simply is the volume of water in which they can move. Space represents the degrees of freedom of locomotion. Protozoa are, of course, of different complexity. The rather undifferentiated amoeba moves mainly passively, but modifies its shape by the extension of pseudopods (through an active plastic deformation of its cell body). The highly differentiated ciliates, e.g. the paramecium, on the other hand, belong to the class of complex eukaryotes (nucleated cells). They are equipped with an intricate system of internal organelles such as microtubuli, contractile microfilaments, an endoplasmatic reticulum etc., which are embedded in the "spider web" of

the three-dimensional microtrabecular lattice (cp. Dustin, 1980; Villee, 1985). The surface of ciliates furthermore may contain sensory bristles, photosensitive spots, food catching devices, cilia for swimming and trichocysts (microscopic harpoon-like structures). This allows for a more diversified behaviour, a certain active movement, attraction and avoidance reactions and simple learning (habituation). Response modification by means of repeated stimulation is also a mechanism which implicitly relates to the time dimension (cp. Dethier & Stellar, 1961).

Complex protozoa may search for food-rich areas, avoid noxious stimuli and obstacles, react to light and detect changes in their chemical environment. These different behaviours have been simulated by rather simple electro-mechanical automata ("turtles"), which move in a random pattern, seek"food"(charging of an accumulator), show phototropic attraction to light, are repelled by objects and show the ability of associative learning (Walter 1953; Bruinsma, 1960).

Nevertheless, what one may call the internal representation of space and time is an achievement of much higher stages of evolution. It demands the gradual emergence of specialized nervous systems and receptors. One step in this development is the emergence of multicellular conducting systems with synaptic interconnections. In radially symmetrical animals a tendency towards centralization of the control-system occurs. The jellyfish possesses two rings of nervefibers. The two bundles are interconnected by a network of neurons and receive information from sense organs which react to light and to changes in position. A more elaborated nervous system with radial nervefibers, interconnected in a circumoral ring is found in the starfish. But still the radial symmetry persists.

The advance of the bilateral body plan brings about a longitudinal axis, a back and front and the necessity of a bilateral nervous system. Two longitudinal nerve bundles are interspersed with ganglia and functionally interconnected. Ganglia are minor aggregations of nerve cells, performing complex switching functions.

The system also receives directed sensory information from the periphery. The longitudinal design introduces a left-right symmetry and a forward directed locomotion. Space becomes differentiated with respect to the body axis.

The development of central ganglia into larger, differentiated brains greatly enhanced the information processing capacity.Additionally a primitive type of awareness seems to appear.Kandel (1979) has studied the mental performances of small nervous systems. The snail aplysia has a simple nervous system, consisting of interconnected arrays of ganglia, but is nevertheless capable of complex learning and adaptive behaviour modification.

The development of well organized teleceptors (which react to radiation energy or pressure waves) allows for the mediation of information from distant objects in space. This means somehow an internalization of external space and its constituents. The ability of organisms to detect their orientation and position in relation to their environment gets essential. Direction finding and homing become important tasks which the organism must be able to carry out.

Tropism (innate, involuntary orientation reaction towards or away from external sources of energy) and taxis (the corresponding actual movement) are some of the behavioural mechanisms which serve this purpose. Organisms employ a wide variety of sources of information. In addition to "normal" sound and light (from a human point of view) one finds for example:

* The orientation of bats in darkness with the aid of a high frequency sonic radar mechanism.
* Some snakes which are able to detect sources of infrared radiation and to integrate this information with visual cues (Newman & Hartline, 1982).
* Nocturnal birds such as owls which are dependent on extremely acute binaural hearing in order to locate moving prey. (Knudsen, 1981).
* Some years ago the ability of birds (e.g. pigeons) was detected to navigate and

find their way in relation to the geomagnetic field.The same ability has also been found in bacteria (Frankel & Blakemore, 1981).

* Some insects such as bees are sensitive to ultraviolet light. Both bees and ants find their home with the aid of the polarization of the sky light. They are equipped with sophisticated detectorsystems which compute the direction of polarization by the comparison of signals from adjacent, counterwise twisted ommatidia (the conical elements of the insect eye) (Wehner, 1976).

Homing already demands a substantial memory. As Karl v. Frisch's ingenious pioneer studies on the social behaviour of the honey bee have revealed, the bee is able to communicate information about directions and distances (v. Frisch, 1954). This means the storage in memory of events which contain implicit information about time, since distance is related to flight time and to the effort which must be spent in order to reach the intended destination.

In vertebrates, especially in mammals, there exists a very complex representation of space and time, comprising both innate dispositions, expectations and ordered memories, including some index of their time-order. The brain is aided by tuned filter- and trigger mechanisms and sophisticated mechanisms for the perception of depth and three-dimensional motion, which utilize both monocular and binocular cues. In humans are coherently moving dots spontaneously organized into visual gestalts, which are perceived as objects, moving in three dimensions (Johansson, 1964, 1975). This is corroborated by stereogram-studies which indicate that information on motion and depth is extracted from the visual input before conscious experience occurs (Ross, 1976). It appears that information concerning motion in depth is processed in two distinct channels, which converge on a single motion-in-depth stage of the visual perception system (Regan at al., 1979).

An organism, which is confronted with the problem of coping with a very complex environment must not only integrate a large amount of different information,

but this must be done in a way which makes it possible to optimize a holistic response. Such a task includes, for example, the probability matching of different sensory messages in space and time. An animal that successfully wants to jump over a cliff, has to judge its own trajectory in relation to distance and initial acceleration.

The eyes deliver primarily information about space, distance and patterns, but secondarily information about time (which is implicit in motion and change). One may mention motion parallax which gives information about the distance of moving objects by comparing the velocity of different retinal picture elements.

The ears give primarily information about events in time, but secondarily information about the location of sound sorces (utilizing phase differences and intensity differences between the ears).

One may now ask if there exists a sense of time in living organisms ? In a physical sense is time measured either by comparing distances which an object moves at constant velocity or by counting the number of cycles from a strictly stationary periodic process. All organisms utilize a variety of periodic processes, ranging from milliseconds to months. Most of them are accompanied by variable electric potentials.

* microoscillations of the eye (about 150 Hz)
* muscular microoscillations (about 10 Hz)
* EEG potentials (1.5 to 30 Hz)
* heart rate, EKG (1 to 3 Hz)
* variation in sleep phases and dream activity (10 to 90 minutes intervals)
* diurnal (circadian) variations in body temperature, blood hormone levels, vigilance and sensory acuity
* monthly sexual cycles
* seasonal cycles in animals (hibernation etc.).

Some of these periodic processes may be independent, some may be reflections of diurnal or seasonal variations in natural illumination or other environmental factors.

Anyhow, the existence of a sense of time in animals can only be proved by inference from observed behaviour. It has, for example, been shown, that insects seem to anticipate seasons by measuring changes in the lenth of the day. While there are several competing models about how this is done, there seems to be an interaction between external and internal periodic processes. Sounders (1976) proposes an internal two-component clock, a combination of oscillator- and hour-glass-type. Part of the model is an external coincidence, e.g. a circadian clock with light-sensitive phase points.

Migration of birds and fish (e.g. salmons) demands both timing and direction finding. The same mechanisms may in some cases be involved in both tasks. In birds timing may be related to the ability to detect changes in the length of the day (similar abilities exist in insects) or to a reaction to a change in the average temperature. An internally controlled change of the endocrine activity is mentioned as another possible mechanism (Crafts & Schneirla, 1950, ch. 3). N-acetyltransferase , for example, seems to be a timekeeping enzyme in the pineal gland. The latter works as a light-controlled biological clock, which communicates time information through the output of melatonin (skin pigment) (Binkley, 1979)

As to navigation, a variety of different mechanisms have been proposed:

* The ability to judge the change in the length of the day during migration (as a function of the latitude)
* The ability to judge the inclination of the arc of the sun with respect to the horison (Holubar, 1969, p. 11).
* Navigation with the aid of an internal magnetic compass.
* The ability to recognize star-patterns during nocturnal flight.

A convincing demonstration of the ability of animals to estimate time intervals is

gained from studies of temporally conditioned reflexes. A naturally occurring stimulus-response pair consists of an unconditioned stimulus (US) and an unconditioned response (UR). The process (chain of events) which connects them may be a reflex. Technically a conditioned response (reflex) is established by a repeated presentation of US together with a suitably chosen "conditioned stimulus" (CS; often light or sound signals) (Pavlov, 1927). [2)]

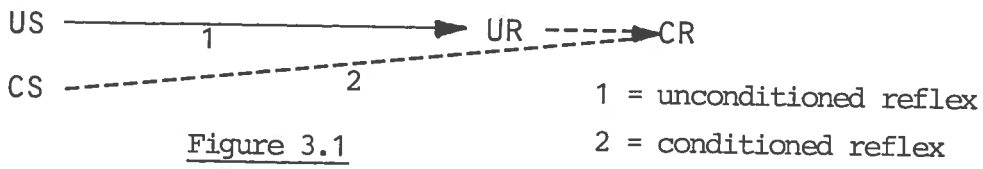


Figure 3.1

By means of associative learning, CS successively gains the ability to elicit UR, even in the absence of US. At this stage UR acquires the nature of a conditioned response (CR). This learning is probably mediated by the thalamus, which acts as a programmable "telephone exchange" for sensory messages.

The time interval between US and CS is mostly critical if one wants to establish an efficient conditioning. Normally both are given simultaneously or with a slight delay between CS and US (figure 3.2, A and B).

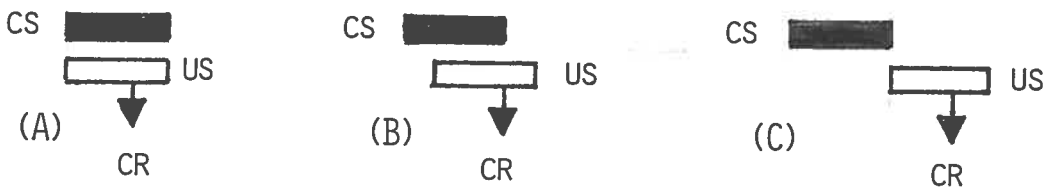


Figure 3.2. A, B, C.

If the US is given directly after the termination of the CS, one speaks of trace conditioning (figure 3.2. C). By increasing the interval Δt between CS and US, a temporal conditioning may be achieved after a sufficient number of repetitions (reinforcements). This means that CR appears at the predetermined time after CS without the presence of US (see figure 3.3.). The time interval Δt between CS and CR is surprisingly stable. Intervals of 10, 15 and 30 minutes have been conditioned in

dogs with an accuracy of about 1 minute (± 3 % in relation to 30 minutes) (Feokritova, 1912). Later experiments on children gave similar results with an accuracy of about 0,3 % at time intervals of 3, 6 and 12 minutes (Holubár, 1969, p.9 ; Kanaev, 1956).

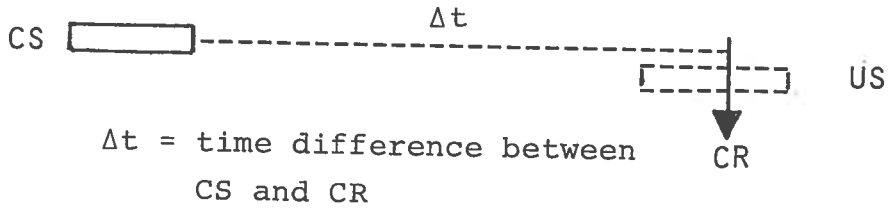


Figure 3.3.

These results strongly indicate the existence of an internal time reference (biological clock). The subject is extensively treated by Holubár (1969). Dr. Delgado's paper, finally, deals more substantially with the brain mechanisms which underly our perception of space and time.

4. Human Consciousness, Space and Time.

The preceding paragraphs apply in most respects to the human species as well, even if there are differences. The human mind allows for an additional source of information in that it is able to analyze and report its own states. In its most advanced form, this implies self-consciousness, the awareness of being aware. This is part of the brain's ability to create highly abstract concepts.

The well developed frontal lobes, which distinguish the human species, seem to be responsible for the handling of abstract ideas and the performance of thought experiments. In this way the frontal lobes prepare the organism for the immediate and more distant future by programming future events.

In a similar way our perceptions are intimately linked to earlier perceptions by means of our memory. We are, for example, in most cases able to tell immediately whether we recognize a person or not. This introduces automatically the time dimension into all perception. The latter has been defined as the interpretation of

an actual message in terms of earlier experience. Perception means the construction of an internal model about our world, presupposing the categories of motion and time (Craik, 1967).

The perception of our world evidently reflects some of its mesocosmic nature. Certain aspects of space and time perception have already been dealt with in the preceding chapter. The ability of human beings to report their experiences gives access to complementary experimental data, such as:

* the estimation of present time intervals,
* the estimation of past time intervals,
* the reproduction of present and past time intervals,
* the comparison of time intervals,
* the production of time intervals

during different experimental conditions (Frankenhaeuser, 1959) without reference to external clocks. The expression of time intervals in terms of conventional units such as minutes or seconds presupposes, of course, an earlier "calibration" of the "internal clock" by repeated learning. This type of experiment makes it possible to study the effects of psychotropic drugs such as tetrahydrocannabinol, mezcaline or scopolamine, which are known to influence the subjective experience of time (Beringer, 1959; Møller, 1951; Reko, 1949). A subject may, while intoxicated, meditate for several hours, thinking that only a short time has passed; in other cases the subjective experience of hours or days may be compressed into a real time interval of a few minutes.

It may be added that the estimation of speed, trajectories and collision points of moving objects seems to be performed at an automatic level. Driving past another car is mainly done automatically, but we have difficulties in giving accurate estimates of the velocities in question without access to a speedometer. In laboratory situations, however, rather good estimationes can be gained (Mashhour, 1964).

There exists a group of phenomena, which are often viewed as malfunctions, but which in fact reveal an additional source of information. Our perception is sometimes distorted by a misinterpretation of "reality", a state of experience, which is called "illusion". It is important to note that illusions may be of different nature and that some illusions seem real to us. The process of perception means a reconstruction of the visual world from external information, where lost or otherwise missing information is substituted by hypothetical information from memory (Vollmer, 1982). If the actual information is largely insufficient, then the cognitive construct to a high extent will contain hypothetical data, which are fetched from memory in order to match the situational context. A typical example is the misinterpretation of natural objects in near darkness, which often results in bizarre or frightening perceptions. This is biologically rational since it induces a careful behaviour which is appropriate with respect to the lack of sufficient information.

There are, however, other optical illusions. Some of them are natural consequences of our mechanisms of visual perception. An essential task of the latter is to stabilize the perception of objects (constancy phenomena). These mechanisms are mainly innate, but are strongly reinforced by experience. They already exist in very young children and include not only depth perception, but also innate expectations regarding the solidity of three-dimensional objects (Bower, 1966, 1971). Optical illusions often arise due to the ambiguity of certain two-dimensional "projections" of real objects.

Other illusions are, however, more difficult to explain, such as the overestimation of vertical distances as compared to horisontal ones (Bartley, 1972, part 2). Some more recet hermeneutic (introspective) studies have given interesting results. They show that visual space corresponds to a hyperbolic geometry and that some illusions result from an attempt to interprete this space in terms of euclidean geometry. This discrepancy explains many distortion illusions, the moon-size illusion

and others. One has derived transformation rules which satisfy the relationship between the external euclidean space and the hyperbolic space of visual perception (Heelan, 1983). [3)]

Our immediate "perceptual knowledge" about space and time has to rely on innate mechanisms, which are adapted to our mesocosmos. The abstract ("scientific") knowledge about the nature of space and time has, however, slowly changed during the millennia of human history, where the most dramatic changes have occurred during the last century.

Animals seem to live in a perpetual "present time", which does not mean the absence of memory or planned action, but probably the absence of an abstract conception of "the past","the present" and "the future". More than 35,000 years ago our ancestors somehow have overcome this natural tendency, which must have demand a substantial effort. One has discovered very old graves which show that the dead were buried together with food, tools and weapons, which presupposes some idea about a future existence and thus a more abstract idea about time (Whitrow, 1973).

It is evident that the great thinkers of ancient Greece (e.g. Zenon, Aristotle or Archimedes) had elaborated analytical conceptions about space, time and motion. Apart from Archimedes, Greek science was mainly non-experimental and built on natural observations and thought experiments. Aristotle's analysis of space and time as something related to the position and change of bodies still reflects the common sense attitude of the natural observer. Our experience of time as a category which orders "past", "present" and "future" would be an example.

It may be mentioned parentetically that the idea of a cyclic time, which was still present in ancient Rome, was fought by the Christian Church , which had adopted the view of a chain of factual historical events instead of myths. A strong advocate of this view was St. Augustine (354 - 430), who become famous for his dictum: "If nobody asks me about time, I know what it is, but if someone asks me to explain

what time is, I don't know it" (Priestley, 1964).

The first essential change towards the modern scientific view came with Galileo and Newton, the second one with Einstein (cp. chapter 1). Modern technology has undoubtedly changed our cultural relation to time. One may think of the increased speed of travel, the rapid transmission of messages by radio, telephone or satellite mediated TV- signals, the processing of vast amounts of information by fast computers or the increased rate of production and automatization. The latter has contributed to an increased standard of living, to more time for leisure, but also to an increased unemployment rate and boredom.

As to the measurement of time, the precision has increased nearly exponentially from a deviation of about 15 minutes/day for clocks of the year 1350 to 10^{-7} s per day for "atomic clocks" of today. The latter employ a resonance interaction between narrowly tuned HF radio oscillators and RF radiation, related to the change of electron spin in atoms such as cesium. The precision of "atom clocks" is so high, that minor variations in the rotation of the earth can be detected. Otherwise the real sun time (i.e. the passage of the sun at the zero meridian, GMT) is still used as an international standard (Whitrow, 1973).

The human organism shows circadian rhythms with interindividually varying efficiency maxima. This fact lies behind the classification of people into "morning" and "evening" types, which is only partially true. The distribution of circadian efficiency maxima has been the object of several studies (see e.g. Appel, 1980; Östberg, 1976). It has, for example, been shown, that students gain significantly better results in written examinations at time points which are close to their maximum phase points as compared with results gained at times close to their minimum phase points.

About 50 years ago Kleitman and coworkers studied the effect on the human organism of artificially changed diurnal (light-darkness) cycles. They showed that in-

dividuals vary with respect to their ability to adapt their "internal clock" to an external one (Kleitman, 1939; Dement, 1974). The problems which are created by shift work and the so-called time chock in connection with air travel are well known today and have promoted the idea of chronohygiene (cp. Appel, 1980, Östberg, 1976). A hypothesis has been proposed which relates the periodic shifts in mano-depressive psychoses to a desynchronization of different phsysiological components in the circadian rhythm.

Time as a phenomenon has fascinated many writers and is the subject of a vast number of literary works, ranging from literal descriptions of time phenomena in epical form to poetic metaphors, stage plays and film stories.

John Boynton Priestley (1964) has written an extensive essay on the notion of time in human history, giving a broad exposé of scientific, artistic and other cultural manifestations, related to time.

There have been profound speculations about the nature of time in relation to human consciousness and to the nature of the universe in large. Some of them are clearly mystical, some may belong to the borderline of scientific research while others are pure fiction, written for entertainment. While they transcend the limits of scientific knowledge, they are also manifestations of human imagination.

The best known example from the category of serious speculation is John W. Dunne's "An Experiment with Time" (1946). Dunne, an aeronautical engineer, tried to explain precognition (in dream states) in terms of a geometric theory about time. He treats time in analogy to space dimensions. An event E in common time (1) may be precognized in terms of an experienced (dream) event D, prior to E. D is related to a separate time dimension (2). But this has the consequence that the present time, the "now" may be prior to E in (1), but sequential to E in (2). Dunne introduces an infinite sequence of time series, enabling a regression from one "time" to another. He explains his model with the aid of a spatial analogue. A

painter depicts a landscape. He draws himself and the easel as part of the picture. The easel in the picture contains a new miniature picture of the whole scene. Theoretically this implies an infinite regression of pictures. Dunne has been criticized on logical reasons by philosophers such as C.D. Broad (Whitrow, 1973). Following Gilber Ryle, Priestley points out that Dunne introduces a sequence of "observing selfs", each one related to his special dimension of time. [4)]

The most typical speculations about time are found in science fiction literature. Famous is today Herbert George Wells' "The Time Machine" (1895). Like many other writers after him Wells treats the time dimension strictly in analogy to space, enabling a motion in time forwards and backwards. Isaac Asimov, a scientifically well educated author, depicts a variety of time travel which presupposes an eternal "time shaft", transgressing through all normal "times" and powered by a future supernova. Asimov thinks obviously in terms of an analogy to an elevator, where a kettle is stationary in space, but moves in time between the "ages" (The End of Eternity, 1959). A.E. van Vogt finally, introduces the "time paradox" in that a person moves backwards in time, meeting his earlier "self" some months backward in the past (The Weapon Shops of Isher, 1954). One may speculate about how the world line of such a person would look like ?

A carricature depicts H.G. Wells in a similar situation, the old Wells meeting himself as a young person (Priestley, 1964).

Psychologically these speculations are of interest since they show how persistently the experience of time is related to the conception of a simgle line, independent of the fact that a one-dimensional line in space is always a mathematical abstraction.

Anyhow, this is a further indication of the mesocosmic adaptation of living organisms to their environment. Most fascinationg, of course, is the fact that

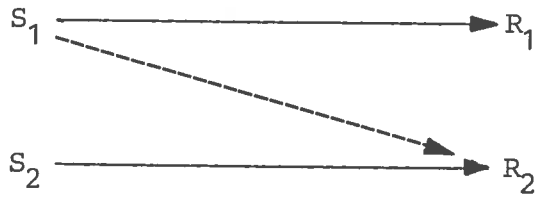
this adaptation includes the internal representation of space and time, but that the human mind at the same time is able to transcend the limitations of the "given" model, thus opening the door to unknown and perhaps unexpected future discoveries.

NOTES

1. The average frequency of sound, which is produced by a string or membrane, depends not only on its size, but also on its tension. In the given example, tension is thought to be"constant",since only size is regarded as a variable. Due to the elasto-plastic properties of tissues, there are, however, other factors which in reality influence (and limit) the available tension.
2. If one touches a hot object, the hand is automatically withdrawn. This very rapid reaction serves the protection of the organism and is called a reflex. It is mediated by very rapidly conducting (80 - 120 m/s) nerve fibers. The simplest (monosynaptic) reflex mechanism uses only four elements: a receptor (detector) unit, an afferent (sensoric) nerve, an efferent (motoric) nerve and an effector unit (muscle). The synaptic junction is located at some segment of the spinal cord. This type of reflex mechanism was already known to and correctly described by Descartes in 1664, although he did not know the nature of nervous conduction. More complex types of reflexes were studied by Pavlov, e.g. the salivary and gastric reflexes. As is well known, the production of saliva is increased by the taste of palatable food. This reaction is mediated by fibers from the autonomous nervous system, which activate exocrine glands (effectors).

   This type of reflex is innate and is called unconditioned reflex (UR). The stimulus, in this case food, is called unconditioned stimulus (US). Now, if one repeatedly presents a signal together with food, an associative learning occurs, which gives a new attribute to the signal: the ability to elicit the reflex in question. The new type of connection which has been established, constitutes a

conditioned reflex (CR). Suppose, that a signal (S_1) normally avokes an attention reaction (R_1). If S_2 denotes the food stimulus and R_2 the salivary response, the following scheme illustrates the natural and learned (conditioned) reactions:



S_1 = signal ; R_1 = attention response; S_2 = food stimulus ; R_2 = salivary response. The response may or may not have the nature of a reflex.
The dotted line (S_1-R_2) represents the conditioned reflex. S_1 now constitutes the conditioned stimulus.

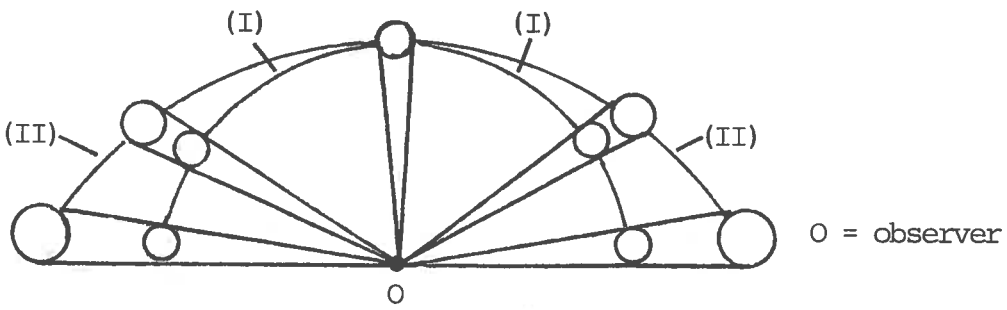
3. Hyperbolic space is one type of so-called non-Euclidean spaces. In the two-dimensional case Euclidean geometry relates to the metric space of a plane and is characterized by the Euclidean axioms (including the parallel axiom: two parallel lines are transected by a third line at the same angle). Meanwhile C.F. Gauss and others have shown that consistent geometries can be designed without the parallel axiom. Essentially these non-Euclidean geometries relate to metric spaces with positive or negative Gaussian curvature, defined by at least one radius of curvature. The surface of a sphere would be an example of a 2-D non-Euclidean space of constant and positive (Gaussian) curvature. Euclidean space may thus be viewed as a special case (infinite radius of curvature). Two other subclasses of space (and corresponding geometries) are called "elliptic" (finite radius, positive Gaussian curvature) and "hyperbolic" (finite radius, negative Gaussian curvature). Visual space is complex in that it is:

1) related to a two-parameter family of hyperbolic metric spaces,

2) divided into a near zone and a distant zone with slightly different properties, and

3) configuration dependent.

The moon illusion illustrates some aspects of the visual space:



(I) = real horizontal sphere; constant apparent size of the moon

(II) = perceived horizontal sphere; perceived (variable) apparent size of the moon.

4. It is not quite clear if Dunne has other reasons for his assumptions outside the attempt to give a logical explanation of precognition. Some of his assumptions are:

1) Objects occupy space and have extension (duration) in the time dimension. They are four-dimensional.

2) Time has length and can be divided into sections such as days or minutes. The length dimension (extension) of time allows events or elements of the physical world to be ordered so that we perceive them in sequence.

3) The brain contains memory traces of distinctly different past events, which we have observed.

4) There exists a three-dimensional "field of sensation", which is stationary with respect to an observer. Certain elements within this field may be the "centre of attention" or the "object(s) of concentration".

5) The "field of sensation" (and the observer) moves in time. In order to observe the consecutive events (elements) in physical time, a new time dimension is needed in which the movement occurs. In order to observe events in this (second) time dimension, a third one is necessary together with a corresponding observer. Hence, each "field of sensation" is surrounded by another one, related to the next "higher" time dimension. This leads to an infinite regress, a series of "times" and "fields of sensation".

The nature of the "observer" is not quite clear. Probably Dunne thinks of a hierarchy of immaterial "observers" (spiritual homunculi or mind entities). In a letter correspondence with A.S. Eddington both agree on serialism, on the fact that time movement does not belong to the Minkowski world and that the "coming" (future) really exists, but that it does not exist in the descriptions of classical physics.

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