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PERCEPTION OF ENVIRONMENTAL QUALITY: SOME BASIC SENSORY CONDITIONS

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ABSTRACT

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A general outline of the modes of operation and the sensitivity of the various sense organs is presented: heat, vision, audition, and touch. Special attention is devoted to some adaptive phenomena.

The human senses are man's windows towards the outside world, through which, more or less at will, observations can be made in it and guided actions can be performed upon it. The senses are in the broadest sense essential for any living system's inherent capability to register relevant changes in environment and to react adequately upon them. There is an immense world of science, of art and of humbug behind these qualifications of relevance of changes and adequacy of reactions.

For deepening the idea of perception of the quality of the environment, whole continents and oceans of this world should be explored. It seems a good approach to start with the seemingly relatively simple description of the functions of the available sense organs as mediators or sensors for detection of these changes and as guides for subsequent (re)actions. In contrast to the complex nature of variables of concern for other disciplines, sensory physiology only refers to physical and chemical methods of measurement of corresponding parameters. Consequently it restricts itself to relatively simple basic problems and questions of which many are still not definitely solved or answered.

Changes in the environment are in the end specified by physical and chemical parameters; likewise, in the stimulation of our senses, physical and chemical processes are involved. Data from distant objects are transferred either by radiation or mechanically. In the latter case, air, water, or the ground or floor serves as a medium for this transfer. For radiation one might think of the aether as the everywhere and the always available medium.

There is almost no limit to the long-wave, low frequency range of the electromagnetic radiation which can be observed as *heat or warmth* by man. Depending on their distance the temperature of sufficiently large surfaces needs to be only a few °C higher or lower than the skin in order to be observed by the temperature sense in the skin. It is merely the balance of emission by the skin to the environment and the absorption in the skin of the incident radiation from the environment that counts.

The temperature sense involves warmth and cold perception. Although common acceptance of specific views on the underlying physiological mechanisms seems now to emerge, there is still sufficient divergence of opinion on main issues. Experiments with a metal contactor cooled well below or heated above skin temperature show the existence of spickle patterns of responsive "spots" for cold which are more dense and widely disparate from the similar patterns of "spots" for warmth. Spot densities range from 0.1 to 25 per cm^2 depending on the body region. The end organ for cold may be just above the superficial venules of the blood circulation at about 0.1 mm below the skin surface. For warmth 0.3 mm depth is a likely figure, just where complex patterns of arterial and venous networks exist. Whatever the exact nature of these endorgans may be — free nerve endings, Krause's end-bulbs, Ruffini cylinders or other exotic elements — they need to become only a few tenths of a centigrade different from the surrounding tissue in order to give a responsive action. Further pecularities are that when touching the skin in a cold spot very warm objects may produce a cold sensation, "paradoxical cold". Similarly there are one or two reports about paradoxical warmth sensations from objects colder than a neutral temperature. The simultaneous elicitation of cold and warmth seems to result in the "heat" sensation. Studies on the temperature sense generally suffer from a very bad test–retest reliability, despite careful control on the obvious experimental variables. However, no doubt this sense governs a very important factor in the comfort—discomfort dimension of environmental conditioning.

When we go further up in the frequency scale of electromagnetic radiation and pass over the short and microwaves region of radiocommunication — which like the far and near infrared of the spectrum can indirectly stimulate the temperature sense, by its warming action of deeper tissue layers — we arrive at the *visible* region of the spectrum.

In a purely formal description of the capabilities of the visual system, it can be said that direction and distance of light-emitting targets and amount as well as spectral distribution of their radiation can be detected. It may be hard to recognize in this specification the overwhelming importance that visual perception has for all our human functions in relation to the environmental world by just meeting the need of the subject for identification and localisation of objects of interest.

As a physical system for optical image analysis, the visual system can hardly be beaten in many respects by any piece of technical hardware. Under favourable conditions it can distinguish differences in distance and difference in intensity of light, of about one promille; the resolving power expressed in angular subtense can be as good as 10 seconds of arc. Tiny differences in spectral qualities of light can be readily and accurately observed as colour differences to the extent that only very advanced special photometric equipment can beat the eye. The visual system, moreover, is operative over the very large range of ten log units of intensity. It takes some time for the eye to reach maximum sensitivity when the brightness level is changed, in particular when it is brought from a high level to a lower one. In the course of this dark-adaptation an initial fast phase, lasting about 5 min is followed by a slower one. Altogether it can take almost half an hour before the adaptation is completed. The fast phase is attributed to the colour vision channels which are supposed to be activated by the cone receptors only. The slow phase is due to the night-vision system connected possibly only to the rods. There are definitely three types of cones — red, green and blue. The nervous networks of cones and of rods have interconnections at various levels in the retina. The centre of the retina, about 2 degrees in angular subtense, contains only cones. An attentive observer directs his eyes and their optics such that the object to be observed is focussed as sharply as possible upon this fovea. Because of the three types of cones, each type serving another part of the visible spectrum, colour vision is a three-dimensional affair at least in the central fovea. We will not discuss the many special theories of colour vision. Widely diverging approaches for mechanistic explanation of the phenomena are still open, in spite of the fast extending amount of known facts.

We now come to the *mechanical senses*, one of which is audition. Classically, the other mechanical senses are brought together in the sense of "*touch*" or *feeling* as the fifth sense next to vision, audition and the chemical senses smell and taste. In recent years the list has been expanded at various times by subdivision of the sense of feeling. Thus, next to the senses of warmth and cold there could be pressure, pain, hunger and thirst, time, a vestibular sense for translation, acceleration, vibration, etc. In the context of this paper it is not relevant to go into much detail with regard to this classification of senses. They can be ordered qualitatively by (1) similarity in sensation, or (2) stimulus-wise, with respect to the objects or forms of physical energy that sets them off, or (3) anatomically by the typology of the endorgans. The last seems to be preferable, except for the skin and its stimuli because not all the endorgans have been identified which may exist in the skin and deeper tissues. Furthermore, one must realize that typical or special sensations may not only be elicited by the corresponding adequate stimulus but almost always by application of electrical and even magnetic currents or fields as well as by certain mechanical actions and by heat. For instance, the retina reacts on and visual sensations can be evoked by electric alternating currents, by γ-rays and weak röntgen radiation in particular, also fast moving heavy ions as is experienced by astronauts in outer space, by electromagnetic alternating fields as occur near weld-transformers, and finally by mechanical pressure of the eye bulbus. Warmth and cold sensations are occasionally evoked by tickling, for instance with a hair, on some locations of the body. The functions of the labyrinth can be tested by irrigating one of the ear canals with hot or cold water. Many other examples might be given.

Because of the role of the tactile sense in identification of objects, we will dwell a bit further on *pressure* sensitivity and related phenomena. There are pressure-sensitive spots whose locations are usually correlated with those of hairs. Application of pressure amounting to about 0.04 erg of energy can be detected, which is 10^8 times the minimum energy detectable by ear or eye. The tactile sense can discriminate a variation of pressure of 10—15% at best. Each feeling of pressure is organized in a pattern having intensive, spatial and temporal aspects. Most important are the patterns commonly called "tickle" and "vibration". On pressure-sensitive spots, usually near hairs and also on the fingertips, amplitudes of vibration of 20 μm for needle point stimulation and of almost 0.10 μm for a large contactor can be felt within a frequency range from around 10 to several thousands per second. This sensitivity is reached for skin temperatures of about 4°C above normal. Visual aids for the blind have been developed on the principle of a limited number of small vibrating points which also use frequency discrimination and which are scanned by the fingertips. In addition to this tactile type of pressure sense there are proprioceptors in the walls of deep-lying blood vessels, in the muscles, in the covering of bones and at the articulations of bones. They are stimulated by the actions of the body itself, including the receptors in the vestibular organ. Displacements of less than half a degree at the shoulder joint, wrists and knuckle of index finger can be discerned just as movements of less than 10 degrees per minute. For the latter, and especially for controlling movements, four types of receptor endorgans in the muscle are responsible. The movement and position of the crista in the ampulla of the vestibular system keeps track on the angular speed whereas the action of the otholith organs on the utricle and sacrule represents the translatory acceleration of the head. There is a very important coordination by way of the central nervous system between vestibular signals and eye position.

A few general considerations may conclude this introduction to the physiological aspects of the senses.

The senses are essential for the detection of significant changes in environmental conditions. Except for the auditory system, all sense organs adapt to completely steady stimuli and make them imperceptible: when we illuminate our indoor environment monochromatically with sodium light we appreciate this illumination after some time as almost neutral and achromatic and translate most contrasts as contrasts of naturally coloured objects; when we stabilize with technical optical gadgets the image on the retina and thus compensate for natural eye movements, voluntary as well as involuntary, the whole visual world fades away and leaves an indeterminate impression of light all over the visual field; this fading of sensations is better known as a clear personal experience for warmth, cold, pain, acceleration, weight and pressure. This ability to make constant stimuli inactive for perception is rather relevant in the appreciation of environmental parameters. Thus a quite wide range of temperatures can be considered as neutral by sufficiently effective adaptation. Ten °C can become an acceptable and agreeable room temperature just as 25°C. When adapted to 10°, a sudden change to 12° can evoke a sensation of warmth, whereas after adaptation to 25°, even 20° can produce a shiver of cold. Mostly these adaptation processes are such that in physical terms the sensitivity for sudden changes from the constant situation is as good as is physically realizable with the "equipment" available.

Another general feature seems to be that, except for the retina by direct vision of the sun, no sense organ can be damaged by natural means. Only man-made stimuli can hurt the sense organs definitely. The peripheral organs also are indefatigable. The various forms of energy in nature and involved in sensory processes do not essentially limit the sensory functions. However, the human ambition to use his sensory systems under unnatural conditions asks quite an amount of joules; for example, watching television indoors in winter in a lightweight suit and the wish to have daylight illumination levels everywhere and at any time. Whole disciplines like illuminating engineering, technical acoustics, and telecommunication engineering take care of and, maybe for a good deal, create the corresponding problems.

For reasons of simplicity we may conclude that our sensory capabilities are best met when the localisation of any relevant object, in relation to the observer as well as in relation to the environment as a whole, is easily, accurately, unambiguously and permanently perceived, including under conditions of movements in traffic or otherwise. Secondly, but not less, the identification of such a relevant object, often connected with its localisation, should meet these requirements.

Perception is a process that occurs in time. All senses are subject to a system of time-processing. Our memory has stored not only spatial structures but temporal structures as well: temporal structures may be even more important components of our life as human beings. We can scan a painting, look at a person and listen to someone else. By selectively attending we can modulate at will the various streams of sensory information for conscious perception and thus master the time-processing of perceptual appreciation of our environment.