Einführung in biologische Sensoren

Physikalische Sensoren können normalerweise nur bestimmte Signale messen (konstanter Meßbereich).

Zusätzlich werden die Meßergebnisse stark negativ von Störungen beeinflußt.

Der natürliche Evolutionsprozeß gestaltet die Adaption der Fähigkeiten biologischer Sensoren.

Einige Beispiele: Chemische Wahrnehmung von Hunden, Ultraschall-Wahrnehmung von Fledermäusen, Augen von Katzen und Vögeln, Lokalisierungsfähigkeiten von Lachs und Tauben.

Sensory Systems and Adequate Stimuli (E)

TYPE	MODALITY	ADEQUATE STIMULI
Chemical	Smell	Odorous substances dissolved in air or water in the nasal cavity
	Taste	Taste stimuli; in mammals the categories of taste experiences are sweet, sour, salty, bitter
	Common chemical	Changes in CO2, pH, osmotic pressure
Mechanical	Touch	Contact with or deformation of body surface
	Hearing	Sound vibrations in air or water
	Vestibular	Head movement and orientation
	Joint	Position and movement
	Muscle	Tension
Photic	Seeing	Visible radiant energy
Thermal	Cold	Decrement of skin temperature
	Warm	Increase of skin temperature

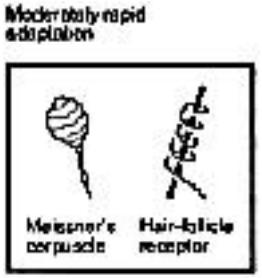
Mechanorezeptoren

Beobachten Sie über die Fingerspitzen die Wahrnehmung der Lage, Oberfläche, Kante, Temperatur eines Objektes. Die Sensoren in Ihrer Haut besitzen verschiedene Adaptionsraten:

- Schnelle Adaption von Pacinian-Korpuskeln

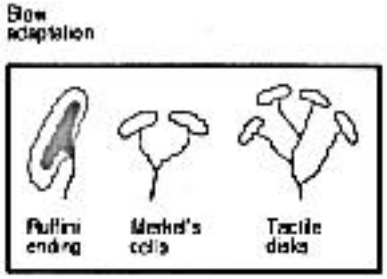
Adaptionszeit: 0,1 s.

- Moderate Adaption von Meissners-Korpuskeln und Haar-Follikeln-Rezeptoren



Adaptionszeit: 1 s.

- Langsame Adaption von Ruffini-Endings, Merkels-Zellen, und Taktile-Disks



Adaptionszeit: 10 - 100 s.

Einige Versuche

Haut:

- Wo ist die sensitivste Stelle auf Ihrer Hand (Zunge, Lippen, Stirn und Genick)?
- Wie hoch ist die räumliche Auflösung?

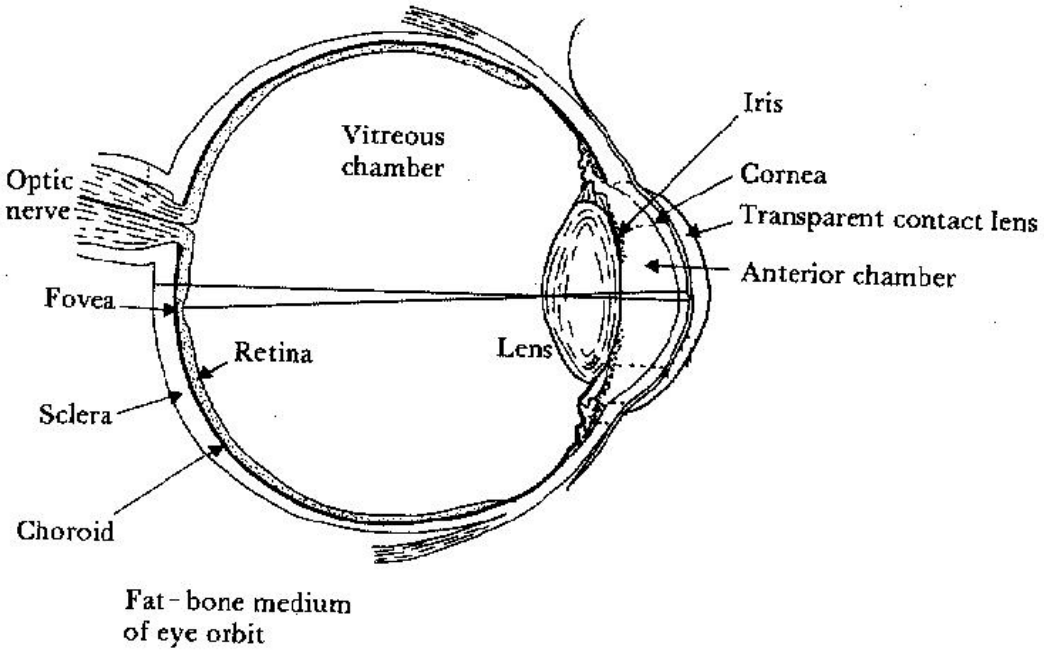
Hörsinn:

- Wie bestimmen Sie die Lage einer Stimme ohne die entsprechende Person zu sehen?
- Wie hoch ist die Auflösung?

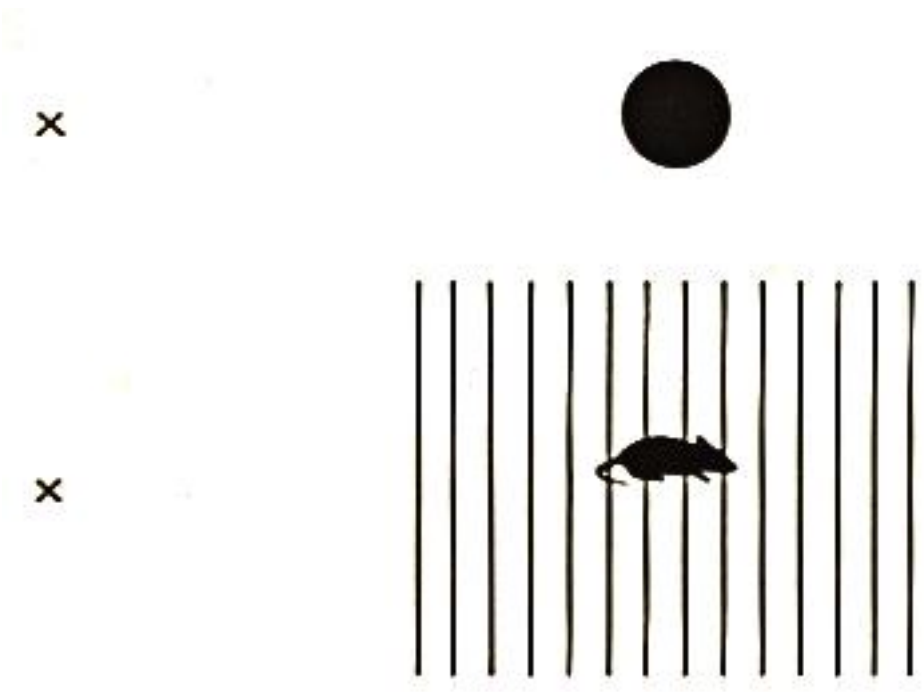
Vision:

- Die Augen von vielen Tieren sind in der Nacht reflektiv. Wozu?
- Photorezeptoren und Blindpunkt

Unser Visuelles System

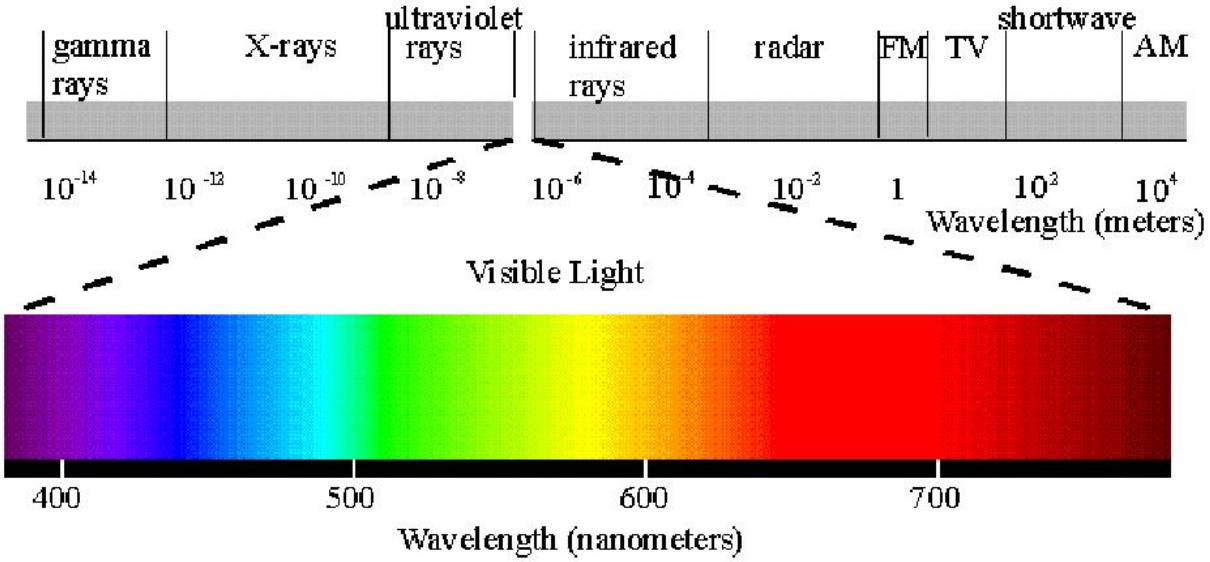


Ein Bild zum Test des “Blindpunktes”



The Basics of Light (E)

The human visual system responds only to wavelenths within a very narrow section of the total spectrum:



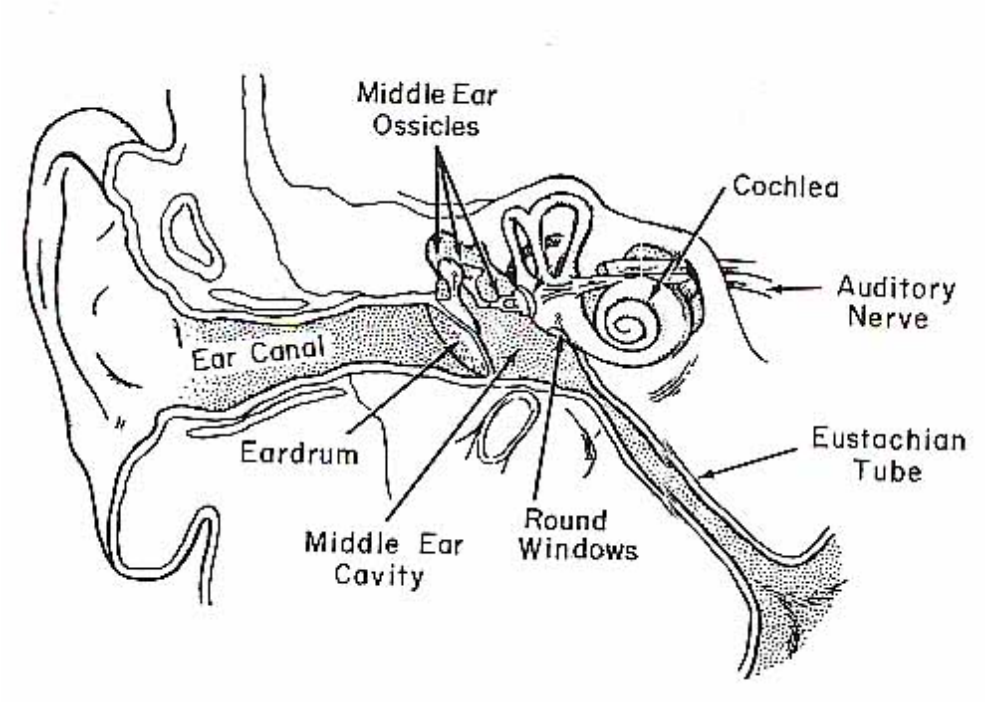
An on-line introduction to visual perception: `http://www.yorku.ca/eye/toc-sub.htm`

Drei Farbdimensionen

HSI-Farbraum:

1. **Intensität** (Helligkeit), welche von dunkel bis hell variiert.
2. **Hue**, welche kontinuierlich über die Farben blau, grün, gelb, orange und rot des Farbkreises variiert.
3. **Saturierung**, welche von leuchtenden zu blassen Farben variiert.

Menschliches Hörsystem



The Basics of Sound (E)

A pure tone is described in terms of two measures: **Frequency** (measured in hertz, Hz) and **Amplitude** or **intensity** (measured as pressure or force per unit area).

Humans hear sound $<$ 20,000 Hz

Bats to 50,000 Hz

One ear can localise sounds, but two ears are better. Cues for binaural hearing.

An on-line introduction to auditory perception:
`http://www.music.mcgill.ca/auditory/Auditory.html`

Was können die biologischen Sensoren besser?

- Hohe Komplexität aber trotzdem biologisch, physikalisch und physiologisch analysierbar.
- Nicht immer hohe Auflösung aber hohe Adaptivität.
- Entstehung über Evolution.
- Redundante, verteilte Wahrnehmung.
- Direkte Abbildung von Signalen zu Symbolen, Konzepten.
- Direkte Nutzung für sensor-motorische Koordination.

A Classification of Movements (E)

Simple Reflex: Stretch, knee jerk, sneezing, startle, eye blink, papillary contraction

Posture and Postural Changes: standing, rearing, lying, balancing, sitting, urination posture

Locomotion: Walking, creeping, running, crawling, swimming,, staking, flying, hopping

Sensory Orientation: Head turning, touching, eye fixation, sniffing, ear movement, tasting

Acquired Skills: Speech, tool use, dressing, painting, sculpting, driving a car, sports, dancing

Three Stages in Skill Acquisition (E)

Paul Fitts:

1. The cognitive stage, in which the subject develops thoughts about different features of the task and the effects of actions.
2. The associative state, during which trial-and-error solutions are attempted and successful strategies are defined.
3. The automatic stage, during which acts are performed with little conscious recognition and variability in performance is reduced. In this stage behaviour relies less on continuous feedback, and it has become more "open-loop" in character.

Emotions - Eight Primary Types (E)

- Happiness
- Fear
- Surprise
- Disgust
- Anger
- Sadness
- Contempt

Memory (E)

Memory has temporal stages: short, intermediate, and long.

STM (short-term memories): “iconic memory” or somewhat longer (minutes).

ITM (intermediate-term memory): memory that lasts one day to several days.

LTM (long-term memory): memory lasts for weeks, months, and years. Even permanent memory.

The capacity of human long-term memory is enormous.

Learning and Memories (E)

Changes in synapses may be mechanism of memory storage.

The nervous system could form and store memories in various ways:

- Physiological changes at synapses could store information.
- Structural changes at synapses could provide long-term storage.
- The Hebbian rule: "When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic changes takes place in one or both cells such that A's efficacy, as one of the cells firing B, is increased."
- Negative changes could also store information in the nervous system.
- Learning can enhance the synapse connections by the Hebbian rule.
- Learning can produce new synaptic connections.

Some major questions to explain learning and memory (E)

- How can very large amounts of information be stored in the nervous system?
- How can at least some memories be stored rapidly in the nervous system yet last a lifetime?
- Are the different attributes of memory (space, time, diverse sensors) processed in separate brain regions?
- How can memories be retrieved accurately and rapidly enough to serve ongoing behavior? How can retrieval be effective not only in the original situations in which memories were acquired but also in novel contexts?
- ...

Language and brain (E)

Proposed cognitive models of the two cerebral hemisphere in humans:

LEFT HEMISPHERE	RIGHT HEMISPHERE
phonetic	nonlinguistic
sequential	holistic
analytic	synthetic
propositional	gestalt
discrete temporal analysis	form perception
language	spatial

Functions and Conducing Polymers

photo-detectors	retina
acoustic sensors	cochlea
strain sensors	spindles
force sensors	golgi tendon organs
touch	skin receptors
pain	nociceptor
taste	taste receptor cells
smell	olfactory epithelium
actuators	muscle
computation	brain
information transmission	nerves
energy storage	ATP / fat
energy delivery	(blood)

Kinesthetic Sensors

(E)

(internal sensors)

- position: potentiometric sensors, capacitive sensors, inductive sensors, magnetic sensors
- angle: brushless inductive sensor, optic encoders (incremental and absolute)
- orientation: gravitational sensors, gyroscopes (mechanical, monolithic silicon, optical)
- velocity: electromagnetic velocity sensors
- acceleration: capacitive, piezoresistive, thermal