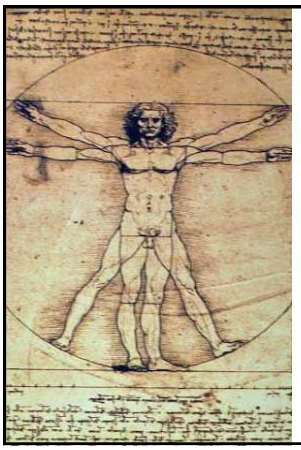

Interactive System
インタラクティブシステム特論(1)

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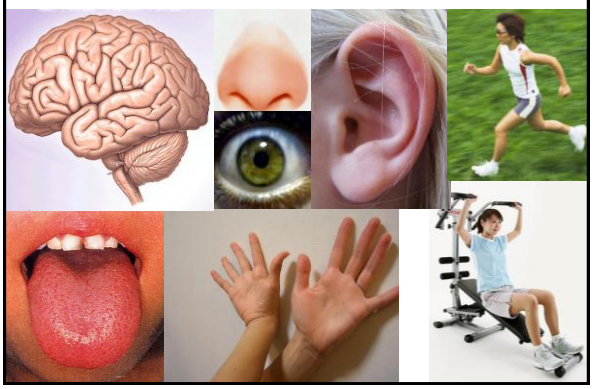
Hash tag #itsys

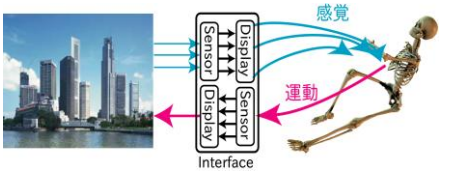
言語 / Language

- 講義は日本語、資料は英語。
  - ✓専門用語は併記
- Lecture in Japanese, handouts in English.

Self Introduction: Research field = Human Interface



Necessary Knowledge for the research



- ヒトの特性／Human perception
- 最新技術(センサ)／Today's sensing technology
- 最新技術(ディスプレイ)／Today's display technology

This Lecture aims to draw rough sketches of
"From Human perception to Optimal Display Design"

Outline

1. 人間計測手法／Measuring Human
2. 視覚／Human Vision System
3. 視覚センシング／Visual Sensing
4. 視覚ディスプレイ／Visual Display
5. 小テスト／Mini Test
6. 聴覚、聴覚インタフェース／Auditory Interface
7. 触覚、触覚インタフェース／Tactile Interface
8. 力覚、力覚インタフェース／Haptic Interface
9. 移動感覚インタフェース／Locomotion Interface
10. 小テスト／Mini Test

小テストと評価 / Mini Test & Evaluation

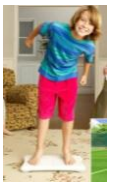
- 講義の目的の一つが「基本知識を得ること」なので、確認のための小テストを行います。
- 完全前ばらし(一週間前)
- 今のところ持ち込み不可
- 評価=出席 (50%) + 小テスト (25% x2)

- As one of the main purpose of the lecture is to have basic knowledge, mini tests are necessary.
- All questions will be open 1 week before the test.
- No carry-on items (tentative)
- Evaluation=Attendance (50%) + Mini Test (25% x2)

Communication

- Handouts on the web
  - http://kaji-lab.jp/ja/index.php?people/kaji/interactive
  - Temporary, 2009 Japanese version. Will be replaced progressively.
- Office hour
  - Anytime. Contact by e-mail first.
- Twitter
  - ID: kajimoto
  - Hash tag #itsys

Today's Topic:
人間計測手法／Measuring Human

ヒトの計測：
- インタラクティブシステムの**構成要素**
- インタラクティブシステムを**評価するため**にも必須

Measurement of human action/reaction
- To be used **as parts of** the interactive system
- To **evaluate** the system

人間計測手法／Measuring Human



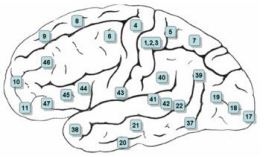


意志から行動までの「どの経路を測るか」で5つの段階
Five layers, *from* our initial will *to* our perception.

●脳活動計測／Measure brain activity.
●神経・筋活動計測／Measure nerve activity.
●自律神経系計測／ Measure autonomic nerve related phenomenon.
●運動計測／Measure motion.
●心理物理実験／Ask the user (psychophysics)

History of Brain Function Observation(1)

- Theory of localization of brain function：
  - 1909：ブロードマンBroadmann made "map" of the brain by visual observation. (microscope)
  - WWI: Better guns = many patients with "partial" brain damage

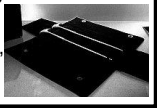


Broadmann's map：
52 regions of the cortex defined based on organization of cells.

History of Brain Function Observation(2)

- 1933：ペンフィールドPenfield
  Before Brain surgery for epilepsy, he stimulated brain directly by electrical needle. while the patients were awake.
  Result: Many functional region were found, including memory, sensory, and action.
- 1940: ロボトミーLobotomy
  Cut frontal lobe of the brain for mental disease, especially for violent patients.
  Result: Became calm, but also became like "robot"⇒Frontal lobe seems to be related to "emotion"
- 1960：X-ray CT gave clear view of the brain, without surgery.



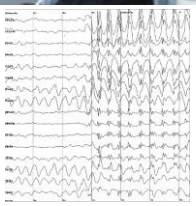


脳機能計測／Measurement of Brain Function

- Not the measurement of brain, but brain function. Must be done during some work. (see, touch, think)
- State-of-the-art measurement technologies are used.
  - Measure "Electrical Activity"
    - 脳波／EEG（brain wave），1929～
    - 脳磁／MEG，1972～
  - Measure "Blood Flow"
    - fMRI（functional MRI），1973～
    - PET，1965～
    - NIRS，1994～
  - Active method
    - Use magnetic stimulator

EEG (Brain Wave)

- EEG: Electroencephalogram
- 21～60 electrodes on the scull skin.
- Good points
  - Cheap!
  - Very fast (ms)
- Bad points
  - Low spatial resolution.
  - Skin-electrode conductance is unstable.
  - Can measure “surface”, but cannot measure “deep region”
- Still used in many interactive systems

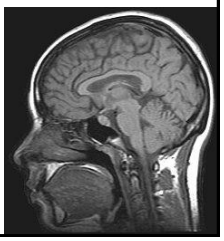


MEG

- MEG:Magnetoencephalography
- Similar to EEG, but measure “magnetic field” induced by electrical current.
- **Very, very tiny magnetic field** (about 1/10^8 of the earth’s magnetic field)
- Superconducting technology is used. (SQUID:Superconducting Quantum Interference Device)
- Good points
  - Very Fast (similar to EEG)
  - Can measure deep region. (magnetic field penetrates everything) .
- Bad points
  - Surface sensors = 2D
  - Current sources = 3D mathematically very difficult to solve (almost impossible)

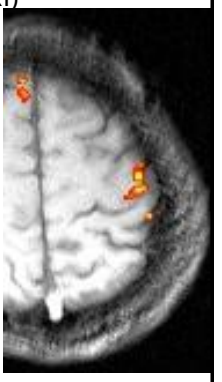
MRI

- MRI:Magnetic Resonance Imaging
  - Very strong magnetic field make protons to “emit” electromagnetic waves.
  - By measuring this waves, can obtain 3D structures.
- Good points（compaired to X-ray CT）
  - No X-ray (=good for body)
  - Bone is not an obstacle
  - 3D data are obtained (X-ray CT:2D)
- Bad points
  - Very strong magnet (3T-): metal cannot be carried on.
  - Takes a few minutes for a single shot.
- Current standard for “brain imaging”



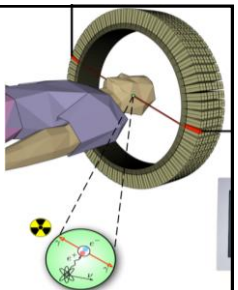
fMRI =functional MRI(機能的MRI)

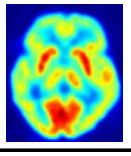
- We must measure brain “activity”, not shape.
  - By using MRI, measure “blood flow”, by measuring two hemoglobins’ ratio.
  - Hemoglobin: container of oxygion.
    - Red = many oxygen.
    - Blue = few oxygen.
- Good point
  - Location is very accurately determined.
- Bad point
  - Requires a few minutes for single shot.
- Current standard for brain functional imaging.



PET

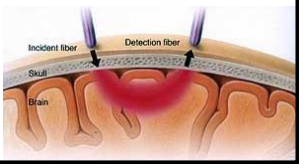
- PET = Positoron Emission Tomography
  - Inject Radioactive ingredient as a “tracer” (O15)
  - The “tracer” collapses, and generate two “γ waves” to the opposite direction.
  - The detector detects the phenomenon.
  - Position is determined by timing measurement.
  - Blood flow can be measured.
- Good point
  - A little faster than fMRI(a few second)
- Bad points
  - radioactive ingredient is necessary.
  - Lower resolution than MRI





NIRS

- NIRS=Near InfraRed Spectroscopy
  - Scull bone is transparent to InfraRed light.
  - Put InfraRed light, and obtain brain surface image.
  - Hemoglobin: container of oxygion.
    - Red = many oxygen.
    - Blue = few oxygen.
- Good points
  - No invasive. Easy to use.
- Bad points
  - Low spatial resolution
  - A few seconds are necessary



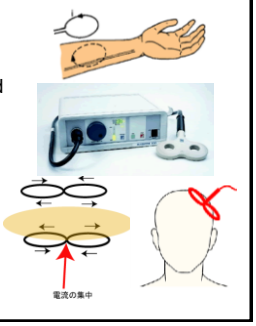
Summary of Brain Functional Imaging

手法 Method	観察対象 Observe	空間解像度 Spatial Resolution	時間解像度 Temporal Resolution
EEG	Electric	Low	High
MEG	Electric	Low	High
fMRI	Blood	High	Low
PET	Blood	Mid	Mid
NIRS	Blood	Mid	Mid

磁気パルス刺激による能動的観察
Active Measurement by Stimulation

Recall Penfield's method.

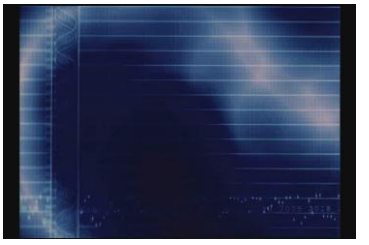
- Magnetic Pulse from outside
  - Small "eddy current" is induced inside the brain.
  - The current stimulates nerves
  - Region can be localized to about 1cm^3



Brain Machine Interface (BMI)

- Growing Field
- Mainly used EEG and NIRS (Fast response is necessary)
- For welfare: for ALS(Amyotrophic Lateral Sclerosis)
  - a progressive, fatal, neuro disease caused by the degeneration of motor neurons.
- Current status: Yes/No, or a few commands.

Video ホンダのBMI



人間計測手法／Measuring Human

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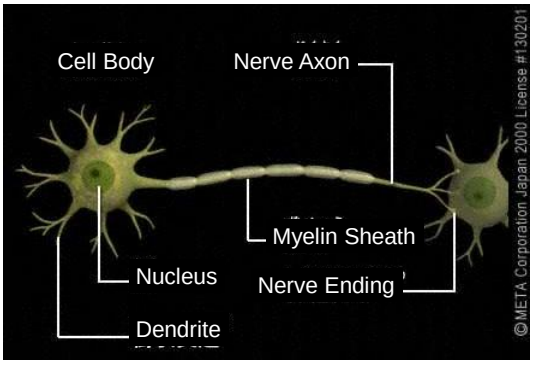
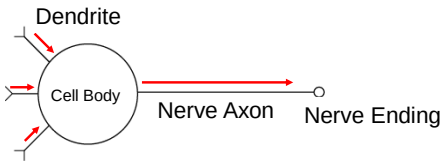
Nerve: Basics

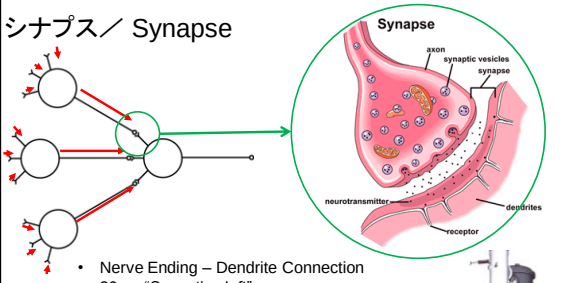


Nerve structure



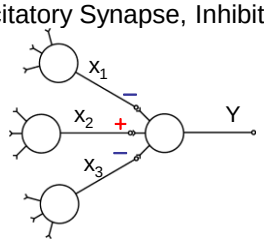
- 樹状突起／ Dendrite: Input Connector
- 細胞体／ Cell Body: Calculator (Summation)
- 軸索／Axon: Output Cable
- 神経終末／ Nerve Ending: Output Connector

シナプス／ Synapse



- Nerve Ending – Dendrite Connection
- 20nm “Synaptic cleft”
  - First Discovery: Electron Microscope
- 1st nerve: Electrical Pulse ⇒Chemical Output
  - Capsules break, and neurotransmitter showers.
- 2nd nerve: ⇒Chemical Input⇒Electrical Current
- “One way” connection
- 0.1-0.2ms necessary

興奮性シナプス・抑制性シナプス
Excitatory Synapse, Inhibitory Synapse

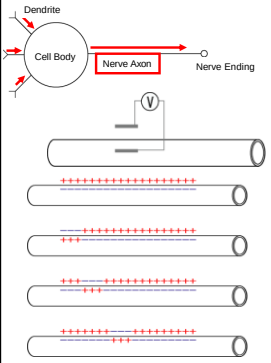


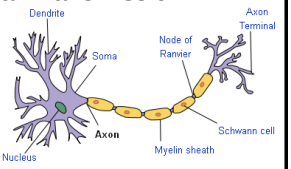
$Y=F(X_1-X_2-X_3)$

F(X)=1 when X≧Threshold
=0 when X < Threshold

- Cell Body: Take Summation Σ
- Excitatory Synapse: Plus(+) input
- Inhibotory Synapse: Minus(-) input
- Synaptic weight change = Learning and Memory

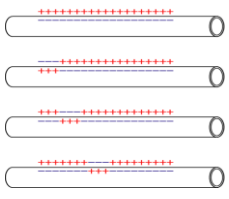
軸索上の電位伝搬／Axonal Transmission

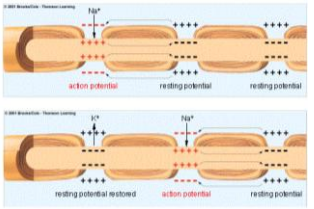




- Chemical “ion” is exchanged via membrane.
- Ion exchange propagates.
- Voltage Difference ~70mV

軸索のタイプ／Axon types





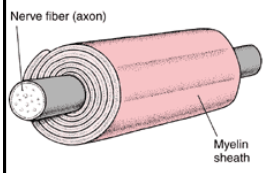
- Axon length: Reaches to 1m.
- ミエリン髄鞘／Myelin Sheath: Insulator
- Electrical Current is limited to very small “gap” (ランビエ絞輪／Ranvier Node)⇒Very Fast “Skip”
- 有髄神経：Myelinated axon=very fast
- 無髄神経：Unmyelinated axon = very slow

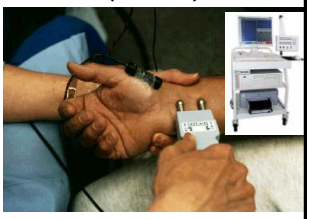
信号伝搬速度／Conduction Velocity

	name	diameter(μm)	velocity(m/s)	role
有髄神経 Myelinated	Aα	15	100	Many muscle nerves
	Aβ	8	50	Many sensory nerves
	Aγ	5	20	Some muscle and sensory nerves
	Aδ	3	15	Fast pain
無髄神経 Unmyelinated	C	0.5	1	Slow pain, heat, cold sensation, etc

- Rule: Thicker = Faster
- Myelinated Axon: Invention of vertebrate animals (animals with back-bone).
- Other animal’s strategy: Thicker the better.
  - ex）Squid’s gigantic nerve (diameter: 0.5mm)

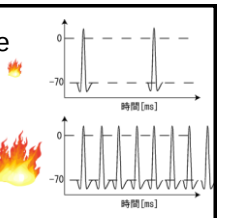
Conduction velocity and diabetic (糖尿病)





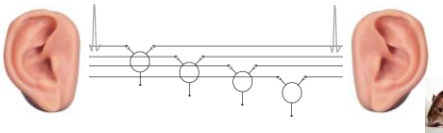
- Diabetic: Quite common disease by taking too much sugar.
- It damages Myelin Sheath so that nerve conduction is inhibited.
- Finally, one cannot sense anything (blind, etc)
- Inspection: measure conduction velocity

Information Coding by the Nerve

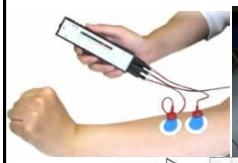


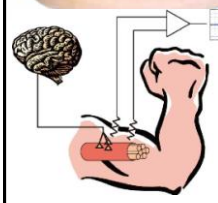
- Repetition Ratio
  - Strong Stimulus⇒High Frequency
  - Single pulse means nothing.
- Timing
  - One nerve is activated when two inputs come simultaneously (at the same time).

(ex) Owl's Sound-Source Detection Mechanism



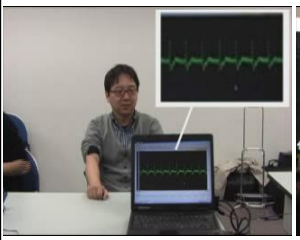
筋電計測
Measurement of muscle fiber activity





•Muscle Nerve ⇒Muscle Fiber Activity
•Relatively easy with differential amplifier circuit (差動増幅回路).
•Problem: Conductive Gel is required.
•他に筋音(Muscle Sound)、光計測等

(ex) 笑いの増幅
Augmentation of Laugh



●Take initial laugh timing by measuring muscle activity.
●Enhance the laugh by using "empathy effect"

人間計測手法／Measuring Human

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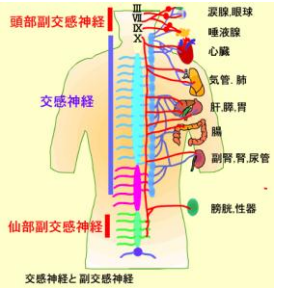
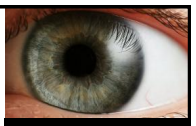
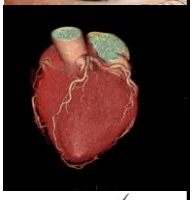
自律神経／Autonomic Nervous System

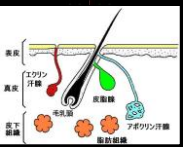
Nervous system that acts as a body control system.
Composed of Sympathetic nervous system(SNS:交感神経)
and Parasympathetic nervous system(PSNS:副交感神経).



Sympathetic nervous system (SNS:交感神経)



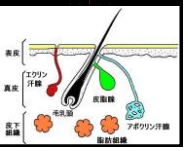




- **Nervous systems for "**Fight and Flight**"** (闘争と逃走)

- Eye Pupils（瞳孔）→Open
- Heart(心臓) →Blood Pressure & Beat ↑
- Skin(皮膚)
  - Sweat Grand(汗腺)→Sweat(発汗)
  - Hair Elector Muscle (立毛筋)→Contract(収縮)
- Blood Vessel(血管) →Expand 拡張（一部収縮）

Parasympathetic nervous system (PSNS:副交感神経)

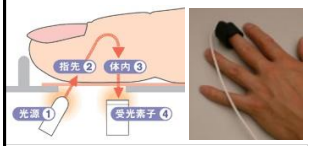


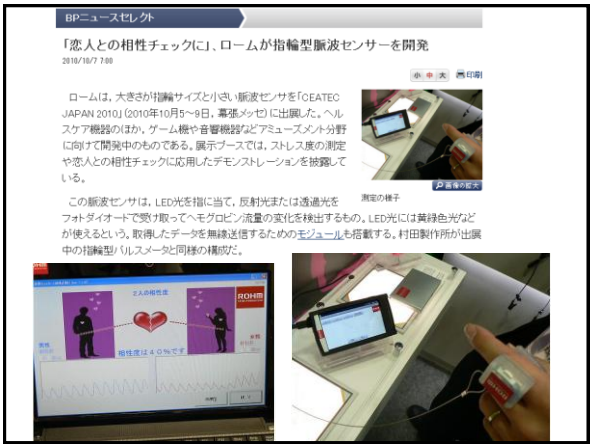
- **Nervous systems for "**calming**"** (沈静)

- Eye Pupils（瞳孔）→Close
- Heart(心臓) →Blood Pressure & Beat ↓
- Blood Vessel(血管) →Contract 収縮（一部拡張）

情動を測定／Measure Emotional State

- Heartbeat & Blood Pressure (心拍数、血圧)
- Pulse Wave (脈波)
- GSR(galvanic skin response，皮膚電気反応)





人間計測手法／Measuring Human

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●心理物理実験／Ask the user (psychophysics)

行動計測／Measuring Motion

- Motion Capture System
  - 光学式／Optical
  - 機械式／ Mechanical
  - 磁気式／Magnetic
  - ビデオ式／Image Processing
- ー長ー短／Pros and Cons
  - 遮蔽問題／Occulusion
  - ワークスペース／Workspace
  - 金属の影響／Effect of Metal

Simpler

- Gaming controllers can be used as a measuring device.
  - 重心動揺計測⇒Wii Balance Board
  - 運動計測⇒Wii Remote
- 簡単なものは自作可能
  - 加速度センサ、ジャイロセンサ

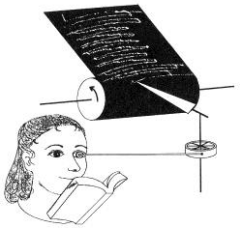



Special Case: How to measure Eye movement

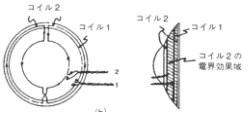
- アナログ測定／Analog measurement
  - コンタクトレンズ／Contact Lens
  - 眼底電位／ Electrooculography
  - 強膜反射／ Limbus Tracking Method
- 画像処理／Computer Vision
  - パッシブ・アクティブな方法／Passive・Active Methods

コンタクトレンズ／Contact Lens

- カイモグラフ(Kymograph)

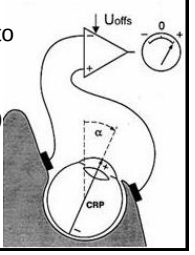



- バリエーション
  - オプティカル・レバー法
    コンタクトレンズに微小ミラー装着
  - サーチコイル法
    コンタクトレンズにコイルを埋込



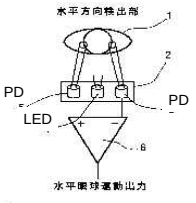
眼底電位
Electrooculography, EOG

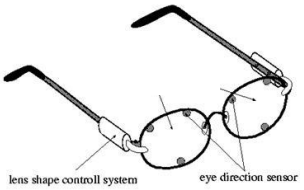
- Horny coat(角膜) has ~1mV positive voltage to Retina(網膜)
- Electrodes(電極) around eyes.
  ⇒Measured voltage is proportional to eye rotation.
- Has wide range (velocity, frequency)
- Accuracy not so good (1 deg~)



強膜反射／ Limbus Tracking Method

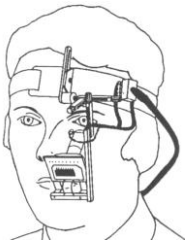
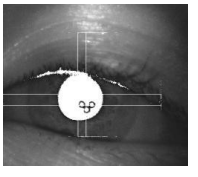
- Emit IR light to the eye, measure reflected light.
  黒目と白目の境界に赤外線照射。反射光計測
- Received light：White part > Black part.
- Good for horizontal eye motion.





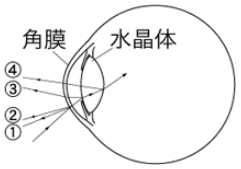
Computer Vision

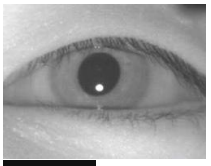
- Capture eye image.
- By image processing (pattern matching), eye center is calculated.
- Reflesh rate = video rate.

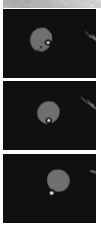



角膜反射／Reflection at Horny Coat

- 点光源の角膜照射時に現れる角膜反射像（プルキニエ像）から眼球運動を計測
- ビデオカメラで撮影⇒画像処理
- 瞳孔中心との相対位置を使う

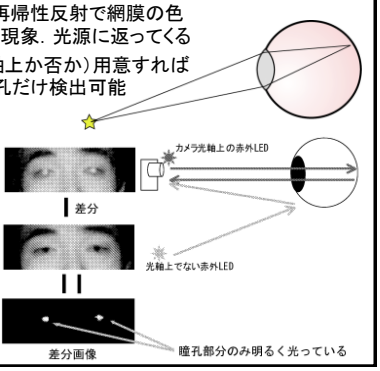






赤目現象の利用／Red-eye Effect

- 目のレンズによる再帰性反射で網膜の色（血管）が反射する現象．光源に返ってくる
- 光源を2種類（同軸上か否か）用意すれば差分画像として瞳孔だけ検出可能



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●心理物理実験／Ask the user (psychophysics)

Psychophysics

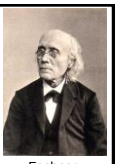
- Measure relationship between subjective sensation and physical stimulation.
  ≒Measure Human's sensing "ability".

- Important value: "Discrimination threshold"
  - Limitation of "difference of two stimuli" **ΔP**, which is perceptible
    ex)
    - P=30g ⇒ ΔP=3g
    - P=3kg ⇒ΔP=300g

- Weber-Fechner's law (1834)
  - **ΔP／P＝Constant**
    Can be applied to most sensation.

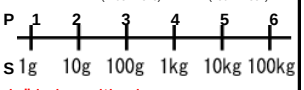
Weber-Fechner's Law

Weber
(1795～1878)

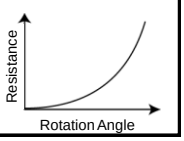


Fechner
(1801～1887)

- P=P(S)
  - P: subjective value of sensation
  - S: physical value of stimulation
  - ΔP = subjective "scale" of sensation
- ΔP/P = Constant
  - Integral of both sides gives **S ∝ logP**

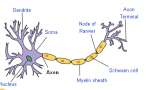


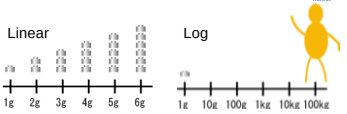
- Conclusion: Our internal "scale" is logarithmic
- ex:
  - Audio's rotary volume



Why Log? = Why not Linear?

Our nerve quantimizes the phenomenon by impulses.
When we have only 6 scales...





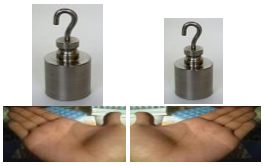
By using Log scale, we can perceive more phenomena.

(ex) CCD cam：20dB～30dB
Huma Eye：80dB(Can see stars and sun

Method of Psychophysical experiment

Purposes
- Measure “Discrimination Threshold” (DT), which gives ΔP
- Measure “Point of Subjective Equality” (PSE).
  - Perceive two different stimuli as “same”.

Discrimination Threshold (DT)
＝What is the necessary difference **for discrimination**



Point of Subjective Equality (PSE)
= What is the value of left weight, which can be perceved as “same” as the right weight.

Major Methods:
Method of Adjustment, Method of Limit, Method of Constant

調整法／Method of Adjustment
極限法／ Method of Limit
恒常法／ Method of Constant

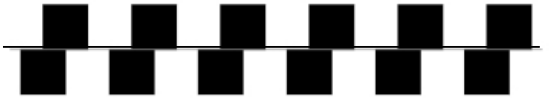
Easy, Rough

↓

Time Consuming, Precise

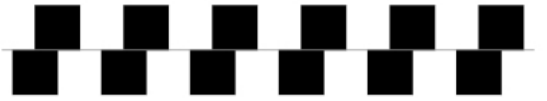
調整法／Method of Adjustment

カフェウォール図形：確かに水平

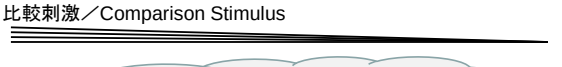


調整法／Method of Adjustment

標準刺激／Standard Stimulus



比較刺激／Comparison Stimulus



~~標準刺激の方が傾いて見える錯覚~~ ~~比較刺激を~~ 回転

極限法／ Method of Limit

ミュラー・リヤー錯視
確かに同じ長さです

極限法／ Method of Limit

1．下降系列／Descending Series

標準刺激
Standard Stimulus

比較刺激
Comparison Stimulus

~~同じく比較刺激の方が長い？上昇法なので＝無理！~~ 回答「小」

このときの比較刺激の長さ＝上閾値／Upper Threshold

極限法／ Method of Limit

2．上昇系列／Ascending Series

標準刺激
Standard Stimulus

比較刺激
Comparison Stimulus

このときの比較刺激の長さ＝下閾値／Lower Threshold

極限法／ Method of Limit

閾値の計算
Threshold Calculation

標準刺激：長さ1．0

上閾値：0.95

下閾値：0.85

この結果から，
•主観的等価点(Point of Subjective Equality)は(0.85+0/95)/2 = 0.90
•弁別域(Discrimination Threshold)は(0.95-0.85)/2 = 0.05

つまり，この「矢印の錯視」によって，
•長さが0.9に縮んで見えることと，
•長さの弁別能力が0.05程度であることが分かった．

恒常法／ Method of Constant

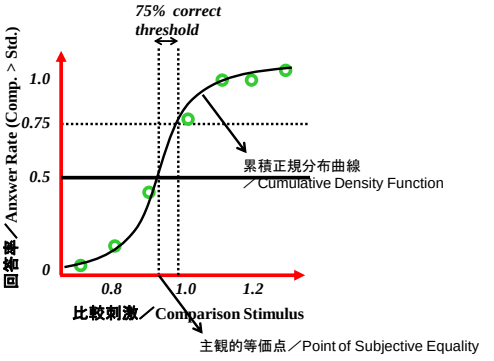
標準刺激
Standard Stimulus

比較刺激
Comparison Stimulus

1. 比較刺激を複数用意する（例では7個）
2. 一個の比較刺激あたりの実験回数を例えば20回とする
3. 合計7×20=140回、「ランダムに」比較し、強制二択させる

比較刺激	「比較刺激の方が長い」	「比較刺激の方が短い」
0.7	1	19
0.8	3	17
0.9	9	11
1.0	15	5
1.1	17	3
1.2	19	1
1.3	20	0

恒常法／ Method of Constant



Today's Summary

Measurement of Human perception is neccesary for interactive system design.

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- 運動計測／Measure motion.
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They can be used both as a **evaluation tool**, and **input method**